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ABSTRACT

This study attempted to determine if students learn science concepts better when laboratories are used to verify concepts already introduced through lectures and textbooks (verification laboratories or whether achievement and retention are improved when laboratories are used to introduce new concepts (directed discovery learning laboratories). The study specifically examined whether seventh-grade earth science students (N=103) introduced to science concepts through laboratory exercises, followed by textbook readings and classroom discussions, learned and retained these concepts better than students who had the concepts introduced through textbook readings or teacher lectures followed by verification laboratories, and if these students also had a stronger preference for science than the latter group of students. Results indicate that students did experience greater achievement and retention when directed discovery learning laboratories were used to introduce new concepts than they did when the same concepts were taught using the laboratory activities for verification. The difference in preference for science between experimental and control groups was not significant. (Author/JN)

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A COMPARISON OF THE EFFECTS OF TWO INSTRUCTIONAL SEQUENCES INVOLVING SCIENCE LABORATORY ACTIVITIES

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A dissertation submitted to the
Division of Graduate Education and Research
of the University of Cincinnati

in partial fulfillment of the
requirements of the degree of

DOCTOR OF EDUCATION

in the Department Curriculum and Instruction
of the College of Education and Home Economics

1985

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I hereby recommend that the thesis prepared under my supervision by Jerry Edward Ivins

entitled A Comparison of the Effects of Two Instructional Sequences Involving Science Laboratory Activities

be accepted as fulfilling this part of the requirements for the degree of Doctor of Education

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CHAPTER I

INTRODUCTION

The introduction is organized into eight categories: 1) historical goals for laboratory activities, 2) recent studies of the role of laboratory activities in the curriculum, 3) success of laboratory activities, 4) statement of the problem, 5) definition of terms, 6) assumptions and limitations, 7) hypotheses, and 8) organization of the study.

HISTORICAL VIEW OF GOALS FOR LABORATORY ACTIVITIES

The task of teachers is to instruct classrooms filled with eager (and sometimes not so eager) students in a manner that promotes good learning experiences. Despite our best efforts, however, some students do not grasp formal science concepts such as fossil formation in earth science, atomic theory in chemistry or protein synthesis in biology. The use laboratory activities to help teach complex concepts and generalizations has been practiced since the 1800's. When Rensselaer Polytechnic Institute opened in 1824, for example, a significant feature of the school was the emphasis placed upon an experimental method of teaching. As applied to chemistry at Rensselaer, the experimental method of teaching meant that (Fay, 1931):

> In giving the course in chemistry, the students are to be divided into sections, not exceeding five in each section. These are not to be taught by seeing experiments and hearing lectures according to the usual method. But they are to lecture and experiment by turns, under the immediate direction of a professor or a competent assistant. Thus by a term of labor, like apprentices to a trade, they are to become operative chemists.

By 1883, a list of forty seven "fundamental experiments that should never be omitted in a high school course" was developed by Charles Wead, a faculty member at the University of Michigan (Moyer, 1976). The Harvard admissions standards of 1886 created a laboratory requirement in physics for secondary school students who wished to enroll at Harvard. The requirement eventually led to a list of sixty one (61) experiments recommended for inclusion in the physics programs of secondary schools. The biological sciences were also characterized as being dominated by the use of the laboratory manual during the 1890's (Hurd, 1961).

In 1920, the National Education Association's Commission on the Reorganization of Secondary Education recommended that:

> the aim of laboratory instruction in science should be to develop a consistent chain of significant ideas related to class work, with the laboratory serving to provide concrete experiences; laboratory work should precede textbook assignments, under

> most circumstances; laboratory work should not be an end in itself and, therefore, detailed microscope work, elaborate drawings, and excessive notebook making were not encouraged (Hurd, 1961).

Unfortunately, using laboratory activities to provide concrete experiences preceding textbook assignments was not widely accepted by the educational community during this time period (Hurd, 1961). In addition, opposition had developed against the secondary schools existing only for the purpose of preparing students for college. As a result, the number of indivduals enrolled in secondary schools increased dramatically. Many students were entering high school but not graduating (Blosser, 1981). Because of the increase in the school population, laboratory activities came to be used largely for confirming and illustrating information presented by the teacher or the textbook, in spite of the recommendations made by the National Education Association's Commission on the Reorganization of Secondary Education cited above. Criticism continued to grow concerning the amount of time students spent on laboratory activities for the apparent lack of educational return. Since teacher demonstrations appeared to be a more economical method, some schools dropped the double laboratory period from the curriculum (Hurd, 1961).

After World War II, which marked the beginning of the "atomic age", there was a renewed interest in the utilization of the laboratory in the secondary curriculum. For example, the 46th yearbook of the National Society for the Study of Education, Science Education in American Schools, stated that laboratory activities should provide pupils with practice in raising and defining worthwhile problems and be conducted so that pupils learn the meaning and use of controls in experimentation. Furthermore, the students should gain practice in analyzing data from problem situations so they learn to test hypotheses and interpret data (Henry, 1947). The desired outcomes of laboratory activities seemed to have shifted from supporting content learning to developing science process skills.

RECENT STUDIES OF THE ROLE OF LABORATORY ACTIVITIES

The push for incorporating laboratory activities in the curriculum continued through the 1960's. During this time many "new" science curricula, such as Biological Sciences Curriculum Study (BSCS), Physical Science Study Committee (PSSC), Chemical Education Material Study (CHEM Study), and Earth Sciences Curriculum Project (ESCP), were developed with the help of the National Science Foundation. The "new"

curricula used laboratory experiences that presented problems for investigation that asked students to determine HOW we know something instead of WHAT we know (Bates, 1978). The goals of laboratory instruction were subtly shifted toward developing an understanding of the nature of science.

Recently, though, money for education has once again become more scarce and the utility of expensive laboratory activities has been questioned (Blosser, 1981, Hofstein and Lunetta, 1980). Current arguments raised against the use of laboratory activities as reported in 1980 by Hofstein & Lunetta (Hofstein and Lunetta, 1980) are:

1. Few teachers in secondary schools are competent to use the laboratory effectively;
2. Too much emphasis on laboratory activity leads to a narrow conception of science;
3. Too maany experiments are trivial;
4. Laboratory work in schools is often remote and unrelated to the capabilities and needs of the children.

As Hofstein and Lunetta stated (Hofstein and Lunetta, 1980):

> There are insufficient data from well-designed studies from which to make unequivocal statements on the role and effectiveness of laboratory work in science teaching.

One explanation for the failure of laboratory activities to demonstrate improvement in science achievement is that the evidence collected has not suggested the best method for incorporating laboratory activities into science classrooms. Blosser, in A Critical Review Of The Role Of The Laboratory In Science Teaching , summarized research done on various methods of integrating laboratory activities into the curriculum and categorized the studies into the following groups: (Blosser, 1981).

a) laboratory vs. no laboratory

b) laboratory vs. two other methods (which may or may not involve lab work)

c) laboratory via a specific curriculum project

d) other variations(such as Lab/ discussion vs. discussion/lab)

e) laboratories involving some student control

f) studies using some form of media

g) studies involving simulations

h) studies emphasizing inquiry/ discovery

As stated earlier, the results of the studies represented in the above categories indicate that if only acquistion and retention of factual knowledge is desired, one procedure is as good as another.

A second explanation for the failure of research to demonstrate the benefit of labs in the science curriculum may be that science educators have had different goals for laboratory instruction at different times and currently cannot agree upon a set of outcomes and objectives for laboratory work. As an illustration, a synthesis of several groups of objectives for laboratory work are listed in Table 1.

The lists of objectives in Table 1 are certainly not inclusive since other lists have been developed by Shulman and Tamir (1973), Andrews (1957), White (1979), and Reif and St. John (1979). The failure of science educators to subscribe to a set of common objectives for laboratory work may be causing the value of laboratory activities to be questioned.

A third explanation for the failure of laboratory activities to demonstrate improvement in science achievement is that many of the instruments used to measure differences among experimental groups were not designed to evaluate the impact of specific laboratory activities on cognitive knowledge. Commonly used instruments for studies have been the Watson-Glaser Critical Thinking Appraisal (Watson and Glaser, 1961), TOUS, the Test on Understanding Science (Cooley and Klopfer, 1961), and WISP, the Wisconsin Inventory of Science Processes (The Regents of The University of

TABLE 1
OBJECTIVES FOR LABORATORY ACTIVITIES*

	National Asso. of Secondary School Principals 1953	Pella 1961	Sund & Trowbridge 1967	Jeffrey 1967	Bradley 1968	Bingman 1969	Hincksman 1973	Lamir 1976	Lancaster 1978
Skills									
Manipulative	x		x	x	x		x	x	
Inquiry			x			x			
Investigative			x	x					
Organizational			x			x			
Communicative			x						
Process skills	x	x	x					x	
Observational (distinguishing like from dislike)	x		x	x	x	x			
Concepts									
Knowledge		x		x	x				x
Verification of knowledge		x							
Drill		x							
Cognitive Abilities									
Critical thinking	x								x
Problem solving/Drawing conclusions/Evaluation (includes formulating hypotheses)	x		x	x	x	x			x
Application		x						x	x
Analysis	x					x			
Synthesis			x			x			
Decision making				x					
Creativity			x						
Provide concrete operations stage							x	x	x
Understanding the Nature of Science									
Scientific enterprise	x	x		x				x	
Scientists and how they work	x	x							
Existence of multiplicity of scientific methods							x		
Interrelationships between science and technology	x								x
Attitudes									
Curiosity	x					x			
Interest	x	x							
Confidence (social adjustment)							x		
Responsibility						x			
Liking science			x			x		x	x

*Consolidated from "A Critical Review of the Role of The Laboratory in Science Teaching" (Blosser, 1981)

Wisconsin, 1967). These instruments measure the student's understanding of scientific processes (WISP), general knowledge about science, scientists, and the ways in which scientists do their work (TOUS), and social and historical phenomena (Watson-Glaser Critical Thinking Appraisal) and such outcomes may not directly relate to the impact that laboratory instruction has on learning.

Economic circumstances, the desire for accountability of teaching methods and some educational research data which cast an element of doubt on the effectiveness of laboratory activities as teaching tools are other possible explanations for the reduced emphasis on laboratory instruction at the secondary level

THE SUCCESS OF LABORATORY ACTIVITIES

Despite the lack of a set of common outcomes and goals for laboratory instruction, several studies have indicated that laboratory activities can and do improve achievement scores. Namek (1968) compared a pattern of inductive-deductive learning activitivies with a lecture/discussion approach and found that the students using the inductive-deductive method earned higher achievement scores than those taught by the traditional approach. Napier (1969) found that the non-verbal

laboratory-oriented method of instruction when compared with a wholly verbal method of teaching produced higher individual scores. Raghubir (1979) reported that students using the laboratory-investigative approach to science instruction had greater understanding of science, greater information retention, and better ability to think scientifically than students taught using the lecture-laboratory approach. Boghai (1979) compared the sequence of discussion and laboratory work in the teaching of a general college chemistry course and found that the laboratory/discussion sequence helped low aptitude students more than the discussion/lab sequence.

Studies by Purser and Renner (1983), Fix and Renner (1979), and Marek and Renner (1979) indicated that laboratory activities improve content achievement of students when compared to a methodology where students are taught with a lecture/laboratory approach or an expository approach. All three of these studies involved a complete revision of the curriculum. Special laboratory activities were written as well as expansion-of-the-idea activities both of which involved several pages of written directions.

Much of the recent science education research is based upon learning theories ascribed to Gagne, Ausubel, and Piaget. However, none of these studies

compared the effectiveness of using laboratory activities to introduce science concepts with the effectiveness of using laboratory activities to verify concepts taught in a unit.

Investigators who support the Learning Cycle based upon Piaget's theory of cognitive development, for example, have studied the effectiveness of laboratory activities by completely redesigning the curriculum, a task that may be accomplished by only a few individuals. Briefly stated, the learning cycle requires an instructor to develop lesson plans based upon three stages: exploration, concept introduction and concept application (Karplus, 1977, Karplus et al., 1977).

Supporters of Gagne and Ausubel have designed few investigations to determine the effectiveness of laboratory activities. Gagne's hierarchical learning theory, for example, states that the sequencing of content determines learning outcomes while Ausubel's assimilation theory suggests that learning only occurs when new knowledge is consciously linked by the learner to existing specific concepts.

STATEMENT OF THE PROBLEM

This study addresses two questions.

1. Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions learn and retain those concepts better than students who have the concepts introduced through textbook readings or teacher lectures followed by verification labs?

2. Do students who are introduced to science concepts through textbook laboratory exercises followed by textbook readings and classroom discussions have a stronger preference for science than students who have the concepts introduced through textbook readings or teacher lectures followed by verification labs?

DEFINITION OF TERMS

The definitions of terms used in this study are described below.

Verification Lab

A verification laboratory activity is the type of lab used to verify a concept or principle already studied in a textbook or presented in a class discussion, or to replicate an experiment already performed by someone else. In this type of activity the student usually knows what the results will be and what to conclude (George et al., 1974).

Directed Discovery Learning Lab

The Directed Discovery Learning Laboratory (DDLL) activity is used to introduce new concepts by directing

students' attention to specific information that is important to learning those concepts. In this type of activity the students usually do not know what the results or conclusions will be, but they do have specific directions to follow. The DDLL labs used in this study were existing textbook laboratory activities that were modified by removing information concerning what the expected outcomes of the exercise might be.

Achievement

Achievement is the score on a paper pencil test that includes knowledge, comprehension, and application questions (Bloom, 1956).

Pretest

The pretest for this study consisted of forty multiple choice, matching, fill-in-the-blank, and short answer questions, and was administered to students one day before the beginning of the study (Appendix B). Twenty questions covered concepts taught in chapter five and twenty questions covered concepts taught in chapter six of Focus On Earth Science (Bishop et al., 1981).

Immediate Test

Immediate tests were tests administered at the completion of each of the two units of study (Appendixes C and D). Each immediate test contained

twenty items consisting of multiple choice, matching, fill-in-the-blank, and short answer questions.

Delayed Test

Delayed tests were tests administered four weeks after completing the second unit (Appendix B). The test instrument consisted of forty items and yielded two scores, one for chapter five and one for chapter six. Each of these subtests contained twenty items.

ASSUMPTIONS AND LIMITATIONS

The following assumptions applied to this investigation.

1. The subjects in the classes possessed the prerequisite skills necessary to begin the study.

2. The subjects in the classes were capable of achieving the objectives.

3. Higher scores on the criterion tests represented greater learning.

4. The units used in the study were identical in content and concept coverage with the only difference being the sequence of the laboratory activities and classroom discussions or textbook reading assignments.

The findings of this study are restricted to generalizations about the total population on the basis of the following limitations.

1. The study was limited to six sections of seventh grade general earth science students enrolled in a suburban junior high school during the fall of 1984. Therefore, the sample was limited in number and geographical location.

2. The study was limited by a short time period. A longitudinal study of the same population might have produced different results.

3. Students may have been aware they were involved in an experiment and performed differently than normal.

4. The study was limited to two teachers. Other teachers may have produced different results.

5. All laboratory activities and tests used in this study were prepared by the investigator. Teachers did not take part in planning the activities.

HYPOTHESES

Three research hypotheses were investigated in this study.

1. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ on achievement measured by tests immediately after completion of a unit of study and statistically adjusted to account for academic ability and initial content-related knowledge from groups doing experiments after related textbook readings and classroom discussions.

2. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ on achievement measured by tests approximately four weeks after completion of a unit of study and statistically adjusted to account for academic ability and initial content-related knowledge from groups doing experiments after related textbook readings and classroom discussions.

3. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ significantly in their preference for science measured by the Subject Preference Inventory and statistically adjusted to account for initial science preference from groups doing experiments after related textbook readings and classroom discussions.

ORGANIZATION OF THE STUDY

Chapter Two contains a review of related literature. The methods and procedures of the study are described in Chapter Three and the data analyses are presented in Chapter Four. The findings, conclusions, implications, and recommendations are reported in Chapter Five.

CHAPTER II

REVIEW OF RELATED LITERATURE

The chapter is organized into seven categories: 1)The purpose of laboratory instruction, 2) Approaches to laboratory instruction, 3) Comparitive studies of laboratory instruction, 4) Learning theories and related research, 5) Affective outcomes, 6) Summary, and 7) Research hypotheses.

THE PURPOSE OF LABORATORY INSTRUCTION

Many studies examining the role of the laboratory in science teaching have concluded that research in science education has not clearly demonstrated the necessity of lab work for learning important science concepts (Bates, 1978, Blosser, 1981, Hofstein and Lunetta, 1980). One reason for the failure of research to demonstrate the necessity of laboratory work may be the lack of a common set of objectives for lab activities. Table 1 illustrates that two objectives were common to six of nine recent studies, one objective was common to five studies, four were common to four studies, three objectives were common to three studies, nine were common to two studies, and eight objectives were common to only one study.

The following comparitive studies illustrate the problems created by investigators who cannot agree upon a common set of objectives for laboratory activities.

APPROACHES TO LABORATORY INSTRUCTION

When introducing a new unit of study, a teacher can use laboratory experiences in various ways to build relationships among the categories of cognitive structure. According to George et. al.(1974), there are five different types of laboratory activities, which differ in purpose and in the amount of teacher control needed during the activity.

A TYPE I laboratory activity is involved with skill development. Teachers who use this type of lab want students to develop and practice psychomoter skills such as measuring length, mass, volume, or density. Teachers may also want students to practice using a particular type of equipment, such as a double pan balance, a bunsen burner, or spectrophotometer. In this type of laboratory situation, it is important for the teacher to be in control in order to minimize breakage of equipment and student injury. Even though this type of activity does not require reasoning ability on the part of the student, it is important for students to achieve laboratory skills.

A TYPE II laboratory activity is used to verify a

concept or principle already studied in a textbook, presented in a class discussion or to replicate an experiment already performed by someone else. This type of laboratory activity, exemplified by the "Energy and Entropy: Phase Change Experiment" found in the Modern Chemistry Laboratory Book (Metcalf et al., 1978), requires the teacher to provide the statement of the problem, what results to expect, and the procedure for the students to follow. Examples of this kind of laboratory activity can be found in laboratory guides associated with many textbooks currently being used.

A TYPE III laboratory experience is called a guided discovery activity. It's purpose is to give students practice in finding relationships in the data collected. The student is given directions without knowing what results or conclusions to expect. The major difference between TYPE II and TYPE III laboratory exercises is the timing of the activity in relationship to the lesson content. A TYPE II lab usually follows a presentation of a concept or principle while a TYPE III lab, such as an ISCS exercise, is performed before the concept or principle is presented. Disadvantages of TYPE III activities are associated with the amount of time involved to complete the "discovery process" and the relative unavailability of commercially prepared activities. Therefore

teachers must either construct their own activities or adapt exercises from programs such as Chem Study, PSSC, BSCS, or ESCP that meet their needs.

In a TYPE IV laboratory activity, the student is given a problem for which the student is expected to develop the methods for collecting data. A sample problem could be: "How can a minnow live in a 10 gallon aquarium for two years without being fed?" With this type of laboratory experience, the teacher does not have the control over the classroom activities that he/she does with TYPES I, II, or III activities. The purpose of a TYPE IV exercise is to provide practice with data collecting skills such as measuring, identifying, and controlling variables as well as to discover scientific concepts or principles. This experience is quite similar to the activities undertaken by scientists because a problem is developed and the researchers attempt to find a solution to it.

As is the case with TYPE III laboratory activities, TYPE IV experiences can be time consuming and frustrating for students if the method is used too often. It also requires a great amount of courage and patience on the part of the teacher, since the student has a more active role in the laboratory proceedings.

A TYPE V laboratory activity places the entire burden of an investigation on the student. The student

must formulate both the problem and the method for collecting data. Furthermore, the student must interprete the data and arrive at a conclusion based upon the results of the activity. In most cases the problem will be identified as a result of class discussions or ideas obtained from the students' own experiences.

In order for the TYPE V investigation to be successful, the student must be proficient in the use of inquiry skills and have good knowledge of the area to be investigated. The teacher must also be comfortable serving as a resource person rather than being the center of learning for all students.

COMPARATIVE STUDIES OF LABORATORY INSTRUCTION

Blosser's publication, A Critical Review Of The Role Of The Laboratory In Science Teaching (Blosser, 1981), emphasizes that research cannot demonstrate the importance of lab activities without identifying a common set of objectives. Her findings indicate that "the interpretation of such studies is dependent upon the assumptions made about the purpose of laboratory instruction. If the acquistion and retention of factual knowledge is desired, one procedure is probably as good as another." To arrive at this statement, Blosser examined a large body of research concerning

the effectiveness of laboratory activities in the science classroom. She divided the studies into two groups. The first group compared the use of the laboratory with some other instructional method or methods, and the second group compared the "traditional" laboratory with some modification designed to improve instruction. The following paragraphs summarize Dr. Blosser's findings.

Laboratory vs. other method(s).

The following will compare laboratory activities with four other methods of instruction: 1) laboratory vs. no laboratory, 2) laboratory vs. two other methods which may or may not involve lab work, 3) laboratory via a specific curriculum project, and 4) other variations.

a) Laboratory vs. no laboratory

Six investigations comparing the laboratory with lecture, no laboratory, lecture-discussion, or lecture-demonstration, resulted in no significant difference (NSD) on attitudes, thinking, chemistry achievement, achieving the objectives of general education, and achievement (Bailey, 1965, Bradley, 1963, Bybee, 1970, Holloway, 1976, Strehle, 1964, Whitney, 1965, as found in Blosser, 1981).

Eight investigations comparing the laboratory with teacher-demonstrations, lecture-only, or discussion, indicated positive results for the laboratory in terms of application of laboratory experiences, critical thinking, learning and retention, attitudes toward school, enthusiasm, and problem-solving ability (Cravats, 1969, Godomsky, 1971, Grozier, 1969, King C.R., 1969, Napier, 1969, Rogers, 1972, Toohey, 1964, as found in Blosser, 1981).

One of the investigations indicated that the teacher-demonstration resulted in better comprehension of concepts (Andriette, 1970, as found in Blosser, 1981).

b) Laboratory vs. two other methods (which may or may not involve lab work).

Nine of the twelve investigations resulted in NSD for critical and scientific thinking, achievement, attitudes, and knowledge, (Baxter, 1969, Blomberg, 1974, Costa, 1974, Dearden, 1959, Dickinson, 1976, Hughes, W. R., 1974, Paulsen, 1979, Spreadbury, 1969, Yager et al.,1969, as found in Blosser, 1981).

Three investigations indicated positive results for manipulative and cognitive skills, attitudes and lab techniques (Coulter, 1966, Dorrance, 1976, Raghubir, 1979, as found in Blosser, 1981).

c) Laboratory via a specific curriculum project.

Two of the five investigations resulted in NSD for manipulative skills or psychomotor abilities (Robertson, 1972, Sullivan, 1972, as found in Blosser, 1981).

Three investigations had positive findings in terms of critical thinking, positive attitudes and achievement (Edgar, 1969, Gunsch, 1972, Johnson et al., 1974, as found in Blosser, 1981).

d) Other variations.

Three of the five investigations resulted in NSD for general education objectives and achievement. A third study found NSD for academically talented pupils, but lower ability seventh graders did better on subsequent tests if they had used the analytic method of teaching (Emslie, 1972, Simpson, 1970, Simpson and Gallentine, 1971, as found in Blosser, 1981).

Two investigations showed an increase in achievement (Boghai, 1979, Reach, 1977, as found in Blosser, 1981).

Traditional laboratory vs. some modification.

The following will compare traditional laboratory some modifications: 1) laboratory involving some degree of student control of instruction, 2) studies using

some form of media such as films, slides, or film loops, 3) studies involving simulations, 4) studies emphasizing inquiry or discovery, and 5) other vairations on the theme.

a) Laboratories involving some degree of student control of instruction.

One investigation indicated NSD for knowledge or critical thinking (Mitchell, 1971, as found in Blosser, 1981). Another investigation reported attitude toward biology more favorable for the experimental group (audio-tutorial) (King, T. J., 1975, as found in Blosser, 1981).

b) Studies using some form of media (films, slides, film loops).

Five of the nine investigations resulted in NSD on achievement, and two process skills (Benzvi et al., 1976, Driscoll, 1974, Dubravcic, 1979, Hughes, J. E., 1972, Hamilton, 1967, as found in Blosser, 1981).

One investigation indicated that the control group achieved sigificantly better (Calentine, 1969, as found in Blosser, 1981). Another found a significant difference for the lab group only on a manipulative skills variable (Sherman, 1968, as found in Blosser, 1981).

Two studies showed the experimental groups to be superior on achievement, and process skills (Brosius, 1965, Townes, 1976, as found in Blosser, 1981).

c) Studies involving simulations.

Two studies indicated NSD in attitude and performance scores (Cavin, 1977, Jones, J.E., 1973, as found in Blosser, 1981) and two investigations showed increases on critical thinking and achievement (Lunetta, 1972, Smith, M. O., 1972, as found in Blosser, 1981).

d) Studies emphasizing inquiry, discovery.

Four of the ten studies found NSD on critical thinking, knowledge of science processes, attitude, achievement, and retention (Allison, 1973, Dawson, 1975, Hoff, 1970, Snyder, 1961, as found in Blosser, 1981). Another study indicated higher achievement scores for expository and lab groups than for the discovery group (Babikian, 1971, as found in Blosser, 1981).

Other investigations indicated positive results in terms of growth in critical thinking, understanding of science, lab and process skills, and interest (Charen, 1966, Egelston, 1971, Mandell, 1967, Serlin, 1977, Sorensen, 1966, as found in Blosser, 1981).

e) Other variations on the theme.

Four of the seven investigations resulted in NSD on understanding the processes of science, learning science content, achievement, and attitude (Campbell, 1978, Grosmark, 1973, Namek, 1968, Smith, A. E., 1971, as found in Blosser, 1981).

The final group of studies in Blosser's review indicated gains on a variety of variables such as the use of formalistic reasoning abilities, formal operators out-performing concrete operators, and on TOUS scores (Campbell, 1978, Namek, 1968, Spears and Zollman, 1977, Whitten, 1971, Ward, 1979, as found in Blosser, 1981).

As stated earlier, the summaries of the comparative studies reviewed by Blosser emphasize the lack of concensus for the goals of laboratory activities. Other problems include research studies that not only assume the definitions of teaching methods under investigation are commonly accepted but also use inadequate instrumentation for assessing the outcomes of variables under study (Hofstein and Lunetta, 1980). Moreover, it is often not clear what kinds of laboratory experiences are being used in a study, or more importantly, what learning theory the investigations are testing.

LEARNING THEORIES AND RELATED RESEARCH

Four learning theories serve as the basis for much of the research in science education as investigators search for effective ways to transmit science knowledge, skills, and positive attitudes to students. Descriptions and research findings of the Hierarchical Learning Paradigm, the Assimilation Theory, the Learning Cycle, and the Information Processing Theory will be presented in the following paragraphs.

Hierarchical Learning Paradigm

The Hierarchical Learning Paradigm will be presented in this section followed by related research.

Hierarchial Learning Paradigm

The Hierarchial Learning Paradigm, first introduced by Gagne (Gagne, 1975), is, according to Stewart and Atkin (Stewart and Atkin, 1982), a behaviorist position, having as it basis the learning of S-R bonds. The basic premises of the hierarchical paradigm is that there are three requirements necessary to build instructional materials (Jones and Russell, 1979). The three requirements, clearly stated objectives, insistence on appropriate practice opportunities, and attention to sequence, are summarized in the following paragraphs.

summarized in the following paragraphs.

Clearly stated objectives: Objectives are specified in measureable terms using action verbs with different verbs used for different kinds of learning outcomes.

Insistence on appropriate practice opportunities: A teacher would use examples, nonexamples, mockups, models, or photos coupled with with appropriate reinforcement as a means to teach a concept.

Attention to sequence: The learners' ability to master higher levels of learning is dependent on their bringing prerequisite knowledge and skills to the learning task. There are superordinate and prerequisite relationships in learning sequences that will be maximally facilitated if students have mastered prerequistie intellectual skills.

Once a terminal objective (usually a rule) is identified, the question is asked, "What would the learner have to do to demonstrate mastery of the rule?" Answers are determined and stated in the form of other behavioral statements which become hypothesized subordinates to the terminal objective. The same question is asked of each of these subordinates. The process is continued until the bottom level skills appear to be simple enough to be performed by the learner population.

According to Gagne (1975), once topics and subtopics have been identified and placed in a suitable sequence, instructional planning can begin to concentrate on the individual unit of instruction. Attention must be paid to a series of external events that can influence the various learning processes. The events of the lesson are described in the following paragraphs.

1. ACTIVATING MOTIVATION. The initial events of a lesson are often designed to awaken motivational states in the learner. The introduction to a lesson often does this by appealing to the interest of the student. The effective teacher is skillful in devising ways to make instruction relevant to student interests.

2. INFORMING THE LEARNER OF THE OBJECTIVE. A specific expected learning outcome of the lesson needs to be established. This is usually done by means of a SET which persists throughout the act of learning. The set may be established when the teacher, or the textbook, communicates to the learner what the learner will be able to do when learning has been completed.

3. DIRECTING ATTENTION. Often, the next event in the lesson is to direct attention to the stimuli which are important to the learning task. Attention may be directed by verbal communication such as "Notice the size of the teeth in the shark."

4. STIMULATING RECALL. This event is often required to be part of a lesson that preceeds new learning. One way to stimulate recall is to simply say "Remember how big the teeth were in the shark we looked at last week?" Communication of this sort will make prerequisite learning available from the student's memory.

5. PROVIDING LEARNING GUIDANCE. Events that form a part of instruction during a lesson may be called learning guidance. These events are differentiated in their emphasis according to the specific learning objective being used. The amount of guidance will vary according to student ability.

6. ENHANCING RETENTION. Techniques for enhancing retention and recall of previously learned information takes the form of spaced reviews.

7. PROMOTING TRANSFER OF LEARNING. The promotion of transfer of learning can be brought about by instruction which provides novel tasks for the student which require the use of previously learned material. The novel tasks often take the form of problem-solving situations.

8. ELICITING THE PERFORMANCE; PROVIDING FEEDBACK. To facilitate learning, the instructor, on occasion, must provide the opportunity for students to demonstrate what they have learned. The display of

knowledge needs to be closely followed with informative feedback from the teacher in order for reinforcement to occur.

Research Findings for Hierarchical Learning Theory

Very little empirical research has been done on the relationship of laboratory activities to Gagne's Hierarchial Learning Theory. Kozma (1982) redesigned a general chemistry laboratory course to include the eight instructional events corresponding to Gagne's phases of learning: activating motivation, informing the learner of the objective, directing attention, stimulating recall, providing learning guidance, enhancing retention, promoting transfer of learning, eliciting the performance and providing feedback. The control or low structured group received only written materials consisting of information introducing concepts and rules needed to conduct a laboratory activity. The treatments consisted of written instructional materials, pre-and post-lab lectures, and laboratory assistance. The results indicated that the high structure groups learned more than the low structure groups.

Assimilation Theory

The Assimilation Theory will be presented in this section followed by related research.

Assimilation Theory

The Assimilation theory, also refered to as the Theory of Meaningful Learning, was first proposed by Ausubel (Ausubel, 1968). There are seven key concepts involved in Ausubel's Assimilation Theory with the most important single idea being meaningful learning. The following paragraphs are descriptions of those key concepts.

"Meaningful Learning" occurs when new knowledge is consciously linked by the learner to existing specific concepts or propositions already known to the learner. To achieve learning, three conditions must be present:

1. The new material must be inherently meaningful.
2. The learner must actively engage in linking new knowledge with existing knowledge.
3. The learner must possess relevant concepts.

"Subsumption" is the incorporation of new knowledge into a specifically relevant existing concept or proposition.

"Integrative Reconciliation" is exploring relationships between new ideas, to determine similarities and differences, and to reconcile real or apparent inconsistencies.

"Superordinate Learning" refers to the reception of new concepts or propositions that relate the

meanings of two or more related, less inclusive ideas.

"Progressive Differentiation" is the elaboration and clarification of meanings of concepts or propositions occuring over time as new subsumption, integrative reconciliation and/or superordinate learning occurs.

"Advance Organizers" introduce a new learning task. They are constructed in such a way to take into account the relevant background ideas already established in the cognitive structure of the learner. The advance organizers serve as a kind of cognitive bridge linking some relevant concept or proposition in the learner's cognitive structure to the new concepts or propositions to be taught.

"Rote Learning" is the arbitrary, verbatim incorporation of new information into cognitive structure. Rote learning occurs when the name of an object, person, or concept has been learned verbatim.

More recently, Novak has modified the Assimilation Theory as originally proposed by Ausubel (Novak, 1980). The major difference can be found in the processes involved in "meaningful learning" where Novak has supported the use of concept maps as a tool for demonstrating how subsumption, superordinate learning, progressive differentiation, and integrative reconciliation work. Concept maps can be used as a

curricular tool, instructional tool, or as an evaluative tool (Stewart, Van Kirk, and Rowell, 1979).

As a curricular tool, the concept map is employed to highlight the distinction between content that is intended to be learned and the content which is to serve as a vehicle for learning.

As an instructional tool, the concept map will highlight for students the large instructional components that correspond to the content of individual lectures in a course.

As an evaluative tool, a student's grade can be based on the degree of correspondence between an "ideal" map and a student map.

Research findings for the Assimilation Theory

Little research has been conducted on the relationship of lab activities to Ausubel's Assimilation Theory. Much of the information found in literature deals with guidelines, such as concept maps, for arranging instructional materials so that the curriculum can meet the "meaningful learning" criteria of the Assimilation Theory (Novak,1980, Stewart, Van Kirk, and Rowell, 1979). West and Kellett (1981), however, did a study to determine if existing semantic knowledge is involved in meaningful learning of specific skills involving chemical solutions with laboratory activities providing relevant prior

knowledge. The role played by this prior knowledge would be the process that Ausubel called subsumption, and the material used could be interpreted as "advance organizers". The outcome of the study indicated that meaningful learning of the skill was enhanced by the addition of advance organizers provided by laboratory activities and that this effect was removed if prior teaching in relevant background knowledge was included.

Learning Cycle

The learning cycle will be presented followed by related research.

Learning Cycle

The underlying principle of the learning cycle is based upon the developmental theory proposed by Jean Piaget (Inhelder and Piaget, 1958). According to Piaget, the intellectual development of humans progresses through four stages in the same order though not necessarily at the same rate. The stages are:

1. sensory motor stage is usually completed at eighteen months.
2. pre-operational stage is usually completed by seven or eight years of age.
3. concrete operational is completed at approximately twelve years of age.

4. formal operational stage are continously developing after approximately age twelve. Only the concrete formal operational levels are generally applicable to secondary students.

To utilize the stage concept, the reasoning abilities of individuals whose development has reached each of the stages must be described. Karplus (Karplus, 1980) has made a list of clues that are helpful in classifying the reasoning patterns of individuals.

When using CONCRETE reasoning patterns, the individual:

> Applies classifications and generalizations based on observable criteria.
>
> Applies conservation logic. A quantity remains the same if nothing is added or taken away, two equal quantities give equal results if they are subjected to equal changes.
>
> Applies serial ordering and establishes a one-to-one correspondence between two observable sets.

When using FORMAL reasoning patterns, the individual:

> Applies multiple classification, conservation logic, serial ordering, and other reasoning patterns to concepts, abstract properties, axioms, and theories.
>
> Applies combinatorial reasoning, considering all conceivable combinations.
>
> States and interprets functional relationships in mathematical form.
>
> Recognizes the necessity of an experimental design that controls all variables but the one being investigated.

> Reflects upon his own reasoning to look for inconsistencies or contradictions with other known information.

An instructor who is interested in incorporating the learning cycle would develop a lesson plan based upon the following three stages; exploration, concept introduction and concept application (Karplus, 1977, Karplus, 1980, Lawson and Renner, 1975).

During the EXPLORATION phase, the students gain concrete experience with the environment by exploring new materials and ideas with minimal guidance. The new experience should raise questions they cannot resolve with their accustomed patterns of reasoning.

The CONCEPT INTRODUCTION permits the instructor to apply a name to the concepts learned during the exploration phase. Concepts may be introduced by the teacher, textbook, film, or another medium.

In the last phase, CONCEPT APPLICATION, the students apply the new concept to additional situations. Concept application activities help the students with conceptual reorganization or self-regulation.

Research Findings for the Learning Cycle

Data from investigations using the learning cycle indicate that using laboratory experiences as exploratory activities, followed by concept introduction and concept application promotes cognitive

development and content achievement of the subjects involved in the studies (Karplus, 1977, Marek and Renner, 1979, Purser and Renner, 1983, Fix and Renner,1979, Kavanaugh and Moomaw 1981, Schneider and Renner, 1980, Kolodiy, 1984). Studies utilizing the learning cycle have often involved complete revisions of the curriculum. Special readings designed to facilitate concept introduction and concept application in a chemistry class , for example, were collected and integrated into the course by Fix and Renner (1979). Another study done by Purser and Renner (1983) provided students with direction sheets designed to stimulate mental disequilibrations as well as lead students to acquire the concrete experience needed for either inventing the concept or understanding the concept when it was later invented for them.

Investigations of the learning cycle also indicate that the curriculum (in terms of content) needs to reflect the findings that sixty-five percent (65%) of secondary students are concrete thinkers, not formal thinkers as Piaget's theory suggests (Herron, 1978, Lawson, 1980, Sayre and Ball, 1975).

Further evidence that exploratory experiences included in process oriented curricula such as BSCS, SCIS, ChEM Study, and etc, are positive in terms of achievement and attitudes can be found in two

meta-analysis studies done by Shymansky and Kyle (1980). The results of the two studies are best summarized by a quote from Shymansky and Kyle.

> The results for the general achievement measure (111 comparisons) are especially interesting. Much criticism regarding the new science curricula focused on the apparent decline of general science knowledge among students exposed to the new programs. At the height of the new curricular movement (and even today) the prevailing notion was that the process goals of the new science curricula were being achieved at the expense of the content goals-- although no comprehensive data base existed for either claim. The data..... show clearly that students exposed to new science curricula performed seventeen percentile points better than students in the traditional group on general achievement measures.

The performance of students using the new science curricula that reflect the learning cycle demonstrate positive results in areas involving higher cognitive skills and more positive attitudes toward science.

Information Processing Theory

The Information Processing Theory will be presented in this section followed by related research.

Information Processing Theory

The Information Processing Theory is based on the idea that individuals learn by asking "cognitive questions" that attempt to make sense out of nonsense in the world around them. This effort to make sense of

the world provides the impetus for learning. According to Smith learning involves the elaboration or modification of three aspects of cognitive structure (Smith, F., 1975). The three aspects of cognitive structure to be explained in the following paragraphs are: 1) a set of categories, 2) lists of distinctive features to specify membership of each category, and 3) a network of interrelationships among the categories.

The first aspect, a set of categories, is the partitioning of an existing category into two or more parts as new information is received. Categorization occurs, for example, when a child learns that there is a difference between a butterfly and a moth or a dog and a cat.

The second aspect, learning "distinctive features", occurs when an individual learns the features or characteristics that determine an animal to be a dog or a cat. The learning involves the modification of cognitive structure to include the development of new feature lists that establish the categories of dog or cat.

The third aspect, learning the interrelationships among cognitive categories, means that the individual would know that a cat could also be a pet, or that a cat is also a member of a larger group of animals that include other kinds of cats. The learning of

relationsips among cognitive categories would mean that individuals build lists of cognitive interrelationships among the categories stored in memory.

The process of modifying or elaborating cognitive structure is a four-stage procedure (Smith, F., 1975):

1. Generating a hypothesis based upon a tentative modification of cognitive structure.

2. Testing the hypothesis by involving some direct interaction with the environment in order to obtain feedback.

3. Evaluating the feedback which provides new information against which the predicted consequence of the original hypothesis can be compared.

4. Confirming or rejecting the modification of cognitive structure.

For the four-stage procedure to work, an individual must access to information under two different sets of conditions. The first of the two sets of conditions is the need for GENERAL INFORMATION which must contain both the problem and the possibility of hypothesizing a solution to the problem. It provides the foundation for generating a hypothesis that will make the cognitive structure a more adequate theory of the surrounding world, and it provides the individual a reason for understanding that a need for learning exists. To learn the difference between dogs and cats, for example, an individual must come upon

situations in which distinctions between them are being made.

The second of the two sets of conditions an individual needs for accessing information is SPECIFIC INFORMATION. Specific information must be directly relevant to the hypothesis the individual has decided to test and must allow that individual to know whether the hypothesized rules for distinguishing dogs from cats really work.

There are three ways that an individual can collect the specific information needed to facilitate the learning process: direct experience, observation (demonstration), and being told (expository).

DIRECT EXPERIENCE must allow an individual to see what solving the problem can be expected to accomplish. In addition, it is important that the experience be guided because the individual will not know where to concentrate his/her attention, rendering the unguided experience wasteful. The direct experience must offer access to specific information which serves as feedback.

DEMONSTRATIONS permit the learner to focus on the most relevant aspects of the problem to be solved. The demonstrator not only provides answers to important questions that the learner should be asking but also what those questions should be.

EXPOSITORY or verbal learning can make a valuable contribution to skill learning, compensating for much of the uncertainty, risk, and irrelevance of learning by experience or observation alone. If, however, verbal learning is used out of context, the acquisition of knowledge through verbal means alone is either difficult or misleading. Facts are the most difficult to learn, and least likely to be remembered when their relevance is not apparent the the learner.

An additional component of the Information Processing Theory is understanding how memory is involved with learning. According to Smith, memory is (Smith, F., 1975):

> --a complex system concerned with nothing less than the selection, acquisition, retention, organization, retrieval, reconstruction and utilization of all our knowledge and beliefs about the world, including our past experience. All of these "processes" or "operations" constitute a single, coherent, interactive system, and that system is memory.

Stewart and Atkin (1982) state that there are at least three memory stores. These include sensory information storage, short-term memory, and long-term memory.

The following are the primary characteristics of a Sensory Information Store (SIS):

A. Maintains detailed sensory information for a brief period of time: 0.1-0.5s.

B. Is an accurate and complete replication of environmental input, much more detailed than information that gets into short-term memory.

C. Has no rehearsal capabilities; that is, there is no "instant replay" feature.

D. Is a time-limited and therefore transient information store.

E. Functions in perceptual processing, pattern recognition, and feature extraction.

The following are the primary characteritics of Short-Term Memory:

A. Maintains information for a few seconds to a few minutes; is a transient information store.

B. Receives information from SIS which has already been encoded by the pattern recognition system; retains the immediate interpretation of events.

C. Is a limited information store; it can only hold 7 plus or minus 2 chunks.

D. Is the site of information storage while one attempts to organize and store information in Long-Term Memory (LTM).

E. Seems to functionally have two different aspects:
   1. An "echo box" where information is quickly lost if not rehearsed.
   2. A "working memory" that not only allows for new material to enter LTM but also probably functions in thinking.

F. Processes information in a serial fashion.

G. Allows information to get so far more or less automatically, although conceptually driven processes are often responsible for extracting information from the environmental input.

The following are the primary characteristics of Long-Term Memory (LTM):

A. Has a permanent and essentially unlimited storage capacity.

B. Retrieves information, which tends to be organized prior to storage in LTM.

C. Requires search procedures for retrieval of information from LTM, which is generally labored and strained.

D. Requires attention for its transition from STM.

In addition to the three memory stores, there are several processes that act upon and serve to expedite the flow of information among the three stores. The functions of the control processes of a memory system can be compared to another type of storage system, the library. Both have an efficient system of organization. The library has the card-cataloging system while the memory system has the aspect of memory called a "monitoring system" that provides instructions for an "interpreter" which performs the examination of the data base and carries out the search procedure (Lindsay and Norman, 1977). In addition to these two aspects of the control processes of memory, there are a set of manipulative rules of logic. These rules of logic include generalization/induction, deduction, class inclusion, and the substantive rules of inference of particular disciplines.

An application of the information processing

theory to education is the utility of a representational scheme called the semantic network. The semantic network attempts to organize the interrelationships among the categories of cognitive structure and is based on the belief that individuals get to long-term memories through organization. The more complex and integrated the network of interrelations in which a particular memory is embedded, the more likely we are to retrieve that memory when we need it.

Sometimes the interrelationships of knowledge in memory creates confusion. For example, the "states" of matter may call forth the images of solids, liquids, and gases for a high school student, but cause confusion to a fourth grade student who thought that "states" were places like Ohio, Kentucky, or Indiana. The meaningful learning instructional strategy called discovery learning would help alleviate confusion since meaningful learning denotes a series of activities intended to give the learner cognitive pegs on which to hang new information. Bruner (1967) suggests that the optimum sequence for instructional strategy would be to move from enactive (concrete) to symbolic (language) representation.

The application of the strategy is the Directed Discovery Learning approach which is used by reading teachers as a catalyst for reading in the content areas (Lewis, 1979). In Directed Discovery Learning, the activities, experiments and guiding questions are used as preparation for reading assignments rather than as ends in themselves.

Research Findings for the Information Processing Theory

The Information Processing Theory has little research relating laboratory activities to learning. According to Stewart and Atkin (Stewart and Atkin, 1982), the Information Processing Theory offers promise because it addresses the shortcomings of the other learning theories. They state, for example, that because Gagne's theory is basically a behaviorist position, it cannot account for propositional and conceptual learning. Furthermore, Ausubel's theory is not complete because it does not encourage the development of routines for manipulating information which means that the theory cannot explain how learning takes place.

Stewart and Atkin believe the Information Processing Theory is promising because it subsumes Piagetian research by suggesting that Piaget's reasoning patterns (serial ordering, classifications

and generalizations, conservation logic, and etc.) are part of the manipulative rules of the control processes of memory.

AFFECTIVE OUTCOME

Subject Preference

Attitudes can be conceptualized as consisting of beliefs, feelings, and actions which can be changed as a result of positive reinforcement, classical conditioning, social pressures, or cognitive dissonance (Zimbardo et al, 1977). An attitude change would probably result in a change in preference for science. The following paragraphs will review research on attitudes.

Dickinson compared the attitudes of students in a lecture-laboratory course with students in a lecture-only course or a lecture-recitation course. The results suggest that students have a more positive attitude toward science when laboratory activities are involved (Dickinson, 1976).

Campbell found that students involved in a learning cycle study for beginning college physics course maintained more positive attitudes toward their laboratory work than did the control group. By the end of the ten-week experiment, the assessed attitudes of

the control students were significantly below the experimental students (Campbell, 1978).

Recently, Renner et al. reported findings on two large scale studies concerned with sequencing learning activities in high school chemistry and physics (Renner et al., 1985). In both cases, students preferred the utility of laboratory activities as an introduction to new concepts rather than a verification.

SUMMARY

A review of the literature revealed that the Learning Cycle paradigm provides evidence supporting the position that laboratory activities improve achievement. But the paradigm is difficult to implement because few teachers possess the expertise for making the curriculum revisions necessary to duplicate the positive results of investigators who support the theory. The Information Processing Theory, on the other hand, seems to be a more feasable approach for studying the effectiveness of laboratory activities, even though it has not been investigated as a potential theory base for promoting learning through the use of directed discovery learning laboratory experiences.

Because individuals attempt to make sense of the world around them by asking "cognitive questions",

laboratory activites could be constructed in a way that encourage students to ask the "cognitive question" that promotes learning (Smith, F., 1975). The verification laboratory activities provided by the text book publishers could be modified into directed discovery laboratory activities. The stated objectives of the verification labs would be replaced with a question (Smith's "cognitive question") that would require the student to formulate a hypothesis concerning the information to be learned. Developing an hypothesis would be the first stage of the four-stage procedure for modifying or elaborating cognitive structure. The remaining three stages would be testing the hypothesis, evaluating the feedback, and confirming or rejecting the modification of cognitive structure. The direct experience of the laboratory activity may provide the student with the specific information necessary for confirmation or rejection. The question posed at the beginning of the lab exercise will also help the student to focus on the "cognitive question".

Students need guidance throughout the performance of an exploratory laboratory experience since it is wasteful for the learner to reinvent techniques that have already been developed. Experiences with laboratory activities should help students place the concepts subsequently introduced by the teacher or

textbook into cognitive categories and give the student mental images that provide the route to long-term memory.

Students enrolled in science classes where laboratory activities are an important component of instruction, generally have more positive attitudes and therefore a preference towards science than students who do not experience laboratory activities.

RESEARCH HYPOTHESES

The three research hypotheses investigated in this study were:

HYPOTHESIS 1. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ on achievement measured by tests immediately after completion of a unit of study and statistically adjusted to account for academic ability and initial content related textbook readings and classroom discussions.

Based upon the literature review, one might expect that there would be a significant difference in achievement between the group experiencing laboratory activities before readings and discussions and the group using laboratory activities as verifications of readings and discussions. At least part of the revisions called for when using the learning cycle, which Renner and others have suggested to facilitate learning, involves a change in sequence of laboratory activities and other instructional approaches.

HYPOTHESIS 2. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ on achievement measured by tests approximately four weeks after completion of a unit of study and statistically adjusted to account for academic ability and initial content-related knowledge from groups doing experiments after related textbook and readings and classroom discussions.

The information processing literature review suggests that students experiencing laboratory activities before related readings and discussions may have greater retention than students who experience laboratory activities as verification labs. Early concrete experiences should, according to different theorists, provide better foundations for building a cognitive structure related to a given content area. Better cognitive structure should result in greater retention of the content learned.

HYPOTHESIS 3. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ significantly in their preference for science measured by the Subject Preference Inventory and statistically adjusted to account for initial science preference from groups doing experiments after related textbook readings and classroom discussions.

The literature review suggests that students who experience hands activities will have a greater preference for science than students who do not experience hands on activities. However, no investigations were found that reported effect of utilizing laboratory exercises to introduce concepts on student preference for science.

CHAPTER III

EXPERMIMENTAL METHODOLOGY

Five components of the research methods used in the study are described in this chapter in the following order: 1) the experimental population, 2) the hypotheses, 3) the experimental design, 4) the experimental variables, and 5) instrument and data analysis techniques.

EXPERIMENTAL POPULATION

This study tested the hypothesis that students taught science concepts introduced through the use of laboratory exercises learn and retain those concepts better than students who have the concepts introduced through textbook readings, or teacher lectures, followed by verification labs. The study also tested the hypotheses that directed discovery learning labs would have a positive effect on students' preference for science in addition to the retention of concepts learned in class. The only difference between the experimental and control groups was the sequence of laboratory activities in the lesson. The experimental group experienced the laboratory exercise at the beginning of the unit while the control group utilized the lab as a verification experience.

The sample for this study consisted of one hundred and three (103) seventh grade earth science students enrolled in six classes in a suburban junior high school in Cincinnati, Ohio during the Fall Quarter, 1984. According to district administrators the families in the attendance area of the school are predominately white, middle class families.

The seventh grade students at the junior high are homogeneously grouped according to academic ability with each class traveling as a self-contained group to English, Math, Social Studies, and Science classes. One group of four teachers instructed half of the seventh grade classes while another group of four teachers instructed the other half.

Earth science is required of all seventh grade students.

HYPOTHESIS

Previous research findings suggest that discovery laboratory activities improve the achievement of students enrolled in science classes. The evidence, however, is based on studies that involved major revisions of the curriculum which makes implementation difficult for most teachers. Therefore, this study attempted to determine if typical textbook laboratory exercises (verification labs) could improve achievement and retention if they were used as directed discovery

learning laboratory exercises that introduce new concepts. A second purpose was to determine if the utilization of directed discovery learning labs promoted a greater preference for science as a subject to study in school.

Three hypotheses guided the study:

A. Students who are taught science concepts introduced through the use laboratory exercises (directed discovery learning labs) learn those concepts better than students who have concepts introduced through textbook readings or teacher lectures followed by verification labs.

B. Students who are taught science concepts with directed discovery learning laboratory exercises demonstrate better retention of concepts taught during the study than students taught concepts introduced through textbook readings or teacher lectures followed by verification labs.

C. Students who are taught science concepts with directed discovery learning laboratory exercises develop more preference toward science than students who experience verification labs.

EXPERIMENTAL DESIGN

The experimental design was a nonequivalent control group design as described by Campbell and Stanley (1963) with a delayed test to measure retention. Multivariate analysis of covariance was employed with both the immediate test and delayed test to compare the performances of the experimental group with the control group after statistically adjusting for the difference in student academic ability and

prior knowledge of concepts included in the study as determined by the pretests. The Subject Preference Inventory was used to measure the science preferences of the students in the experimental and control groups before and after the study. Analysis of covariance was used to determine if the adjusted post-treatment difference between the groups was statistically significant.

The study included two seventh grade earth science instructors, each of whom taught one "advanced" and two "general" classes. Teacher A used the directed discovery learning lab treatment with one "advanced" and one "general" class while the second "general" class served as the control and did not receive the treatment. Teacher B used the directed discovery learning lab treatment with one "general" class while the remaining "general" and "academic" classes served as the controls. The design is represented in Figures 1 and 2.

FIGURE 1

Sequence of Laboratory Activities

TREATMENT

SAI O1 O2 X1 X2 O3 X3 X4 O4 O5 FOUR WEEKS O6

VERIFICATION

SAI O1 O2 X2 X1 O3 X4 X3 O4 O5 FOUR WEEKS O6

SAI= Otis-Lennon Scholastic Ability Index achievement test administered to all seventh grade students.

O1 = Pretest on attitude using the Subject Preference Inventory Test

O2 = Achievement on pretest for chapters five and six.

X1 = Laboratory activity for chapter five.

X2 = Textbook reading and classroom discussion for chapter five.

O3 = Achievement on posttest for chapter five.

X3 = Laboratory activity for chapter six.

X4 = Textbook reading and classroom discussion for chapter six

O4 = Achievement On Posttest for chapter six

O5 = Posttest on attitude using the Subject Preference Inventory Test.

O6 =Achievement On Delayed Test for chapter five and six

FIGURE 2

The Assignment of Teachers to the Treatment Groups with Ability Levels of Homogeneously Grouped Students Identified.

	Teacher A		Teacher B	
	High Ability	Low Ability	High Ability	Low Ability
Directed Discovery Learning Lab	X	X		X
Verification Lab		X	X	X

The English teachers collected data used to compare student subject preference in the treatment and control groups by administering a Subject Preference Inventory (SPI). English teachers administered the SPI to reduce the possible influence on science scores.

The instruction in this study consisted of two chapters from Focus on Earth Science published by Charles E. Merrell Publishing Co. (Bishop et. al. 1981). Chapter five dealt with minerals while chapter six covered igneous and metamorphic rocks. All laboratory activities used by the control group were Type II laboratory activities, verification, and the labs used by the experimental group were Type III

laboratory activities, guided discovery/directed discovery learning labs (George et al., 1974).

The initial Directed Discovry Learning Lab (DDLL) activity for chapter five required the students to grow crystals in order to determine the two different ways that crystals can be formed (Appendix E). The second DDLL exercise had the students identify twelve (12) rock forming minerals through the use of a "key" (Appendix F). In the second activity, students performed various tests on minerals to determine the mineral properties so they could use a mineral classification chart to identify the mineral.

In the first DDLL activity of chapter six the students heated substances and cooled them at various rates (Appendix G). After the substances cooled, the students compared the sizes of the crystals and related the cooling rates to intrusive and extrusive rocks. The strategy of the second DDLL was to relate crystal formation to the formation of igneous rock by focussing upon the formation of metallic silicate crystals from silicates and various metallic compounds (Appendix H). The third exercise in chapter six helped students understand the effect of magma on surrounding rock (Appendix I). An egg was placed in a vinegar solution for three days so that students could visualize that the surroundings of a substance can cause it to change.

The final DDLL of chapter six was an activity in which a "key" was used to identify igneous and metamorphic rocks (Appendix J). Students offered suggestions as to what rock characteristics could be used to identify the various rocks. The characteristics were written into a data table.

EXPERIMENTAL VARIABLES

The independent and dependent variables and the covariates of this study are described below.

Independent Variable

The independent variable tested in this study was the sequencing of laboratory activities within a unit of instruction. Directed discovery learning laboratory activities were used to introduce concepts to the experimental group before textbook readings and classroom discussion, and verification laboratory activities were used to reinforce concepts for the control group after textbook readings and classroom discussions.

Dependent variables

The dependent variables in this study were the subject preference of students, cognitive achievement, and retention.

Subject Preference

Students in both experimental and control groups

were asked by their English teacher to complete a Subject Preference Inventory (SPI). The students did not know the SPI was related to the study.

Achievement

Students achievement was measured at the end of each unit of study. The test items consisted of twenty multiple-choice, short answer, and fill-in-the-blank questions.

Retention

A forty item test containing multiple-choice, short answer, and fill-in-the-blank questions was adminsitered four weeks after the conclusion of the study to measure student retention. Twenty items related to chapter five and twenty to chapter six.

Covariates

The covariates in this study were scholastic ability and prior knowledge as measured by the pretest.

Scholastic Ability

All seventh grade students in the school were administered the Otis-Lennon School Ability Test Form R in September of 1984 (Harcourt Brace and World, Inc, 1979). The reliability of the Otis-Lennon School Ability Test for the seventh grade as determined by the Kuder-Richardson procedures was .93. Differences in the scholastic ability of the students were

statistically adjusted by using multivariate analysis of covariance.

Pretest Scores

Students were administered a test at the beginning of the study to determine their mastery of concepts included in the unit. The pretest contained twenty (20) questions from chapter five and twenty (20) questions from chapter six of the textbook "Focus on Earth Science" (Bishop et al.,1981). Preinstructional knowledge was statistically adjusted by using multivariate analysis of covariance.

INSTRUMENTS AND DATA ANALYSIS TECHNIQUES

Three achievement tests were developed from questions written by the textbook publisher (Charles E. Merrill Publishing Co.) and from teacher constructed tests. The reliability of all achievement tests were estimated using the split-half method and the Spearman Brown correction formula and are reported in Table 2. The same forty item test was used as both the pretest and delayed test (Appendix B). The reliability for the subunits of the pre and delayed test composed of twenty questions from chapter five and twenty questions from chapter six was .80 for chapter five and .57 for chapter six. A second test (Appendix C) was administered as the immediate posttest at the end of

the first study unit (Chapter 5) and had a reliability of .69 while a third test (Appendix D) administered at the end of the second study unit (Chapter 6) had a reliability of .66. The two immediate posttests at the end of the two units consisted of twenty items each. Test items were paired with the stated objectives of the units and measured the students' knowledge, comprehension and ability to apply the concepts taught in the unit. A panel of two science educators reviewed the test items to validate the match between the stated objectives and the items.

Table 2

RELIABILITY OF ACHIEVEMENT TESTS

	chapter five	chapter six
immediate posttest	.69	.66
pretest and delayed test	.80	.57

Since the achievement scores on any of the post-tests could have been affected by the what the students knew before the beginning of the study and by their scholastic ability, correlations among the variables were computed to determine which variables related to the post achievement measures. To determine the effectiveness of the treatment, multivariate analysis of covariance was used to compare treatment and control groups and adjust for differences in

scholastic ability and preinstruction knowledge.

Multivariate analysis of covariance was also used on the delayed test scores to compare the retention of concepts by the experimental and control groups. The same covariates were used as in the immediate tests.

The Subject Preference Inventory (SPI) was used to measure student preference for science (Appendix A). Kendall's coefficient of consistence was used to estimate the reliabilty of the SPI measure and yielded values of .94 on both the pre and post measures. Analysis of covariance with the preinstruction science preferences as the covariate was then used to analyze the effect that sequencing lab activities had on students' preference toward science.

CHAPTER IV

EXPERIMENTAL RESULTS

In this chapter, the research hypotheses are stated in the null form and data from the study are described and analyzed. The performance of the verification lab group is compared to that of the directed discovery learning lab group which did the experiments before classroom discussions and textbook readings. Comparisons between the two groups using immediate and delayed achievement measures and immediate preference for science are presented in the following order: (1) overall effects of the sequence of lab experiences on immediate achievement test scores; (2) effects of the sequence of lab experiences on immediate achievement test scores for individual chapters; (3) overall effects of the sequence of lab experiences on delayed achievement test scores; (4) effects of the sequence of lab experiences on delayed achievement test scores for individual chapters; (5) effects of the sequence of lab experiences on student preference for science as measured by the subject preference inventory.

NULL HYPOTHESES

Research hypotheses written in the null form facilitate statistical testing of the hypotheses. The null hypotheses of this study were:

1. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ on achievement measured by tests immediately after completion of a unit of study and statistically adjusted to account for academic ability and intitial content-related knowledge from students doing experiments after related textbook readings and classroom discussions.

2. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ on achievement measured by tests approximately four weeks after completion of a unit of study and statistically adjusted to account for academic ability and initial content-related knowledge from students doing experiments after related textbook readings and classroom discussions.

3. Students using laboratory experiments to introduce concepts before related readings and discussions will not differ significantly on their preference for science measured by the Subject Preference Inventory and statistically adjusted to account for initial science preference from students doing experiments after related textbook readings and classroom discussions.

DESCRIPTION OF DATA

Prior to the treatment, subjects in both groups were administered the Subject Preference Inventory which yielded a preference for science score ranging from zero to five and achievement tests for chapter five and chapter six. Upon completion of each chapter, students were administered a twenty-item immediate posttest. Near the completion of chapter six, students

were administered the Subject Preference Inventory a second time. Approximately four weeks after completing chapter six, subjects were administered a delayed achievement test containing twenty items related to chapter five and twenty items related to chapter six.

The maximum achievement test score was twenty for each chapter to be studied. The pretests and posttests yielded two scores each, the number of correct responses to twenty items related to chapter five and the number of correct responses to twenty items related to chapter six. The mean scores on the pretest for chapter five were 5.80 for the group to experience labs before other teacher-directed activities (the experimental group) and 6.79 for the group to experience labs after other teacher-directed activities (the control group). The standard deviations were 2.13 and 2.17 respectively. The split-half reliability for the test used as a pretest and delayed posttest for chapter five was .80. The mean scores on the pretest for chapter six were 7.86 for experimental group and 8.07 for the control group with standard deviations of 3.00 and 2.41 respectively. The split-half reliability for the test used as a pretest and delayed posttest for chapter six was .57.

The immediate posttests means for chapter five were 13.88 for the experimental group and 14.70 for the

control group with standard deviations of 3.68 and 3.50 respectively. When these scores were adjusted to account for differences in academic ability as measured by the Otis-Lennon School Ability Inventory and differences in preinstructional knowledge as measured by the pretest, the adjusted means were 14.35 for the experimental group and 14.38 for the control group. The split-half reliability estimate for the immediate posttest for chapter five was .69

The means for the twenty-item immediate posttest for chapter six were 11.98 for the experimental group and 11.05 for the control group with standard deviations of 3.32 and 2.95 respectively. After adjusting these scores to account for differences in academic ability and preinstructional knowledge, the adjusted means were 12.34 for the experimental group and 10.80 for the control group. The split-half reliability estimate for the immediate posttest for chapter six was .66.

The delayed posttest was a readministration of the pretest which contained twenty items related to each of the two chapters studied, a total of forty items. The mean scores for the chapter five delayed test were 9.86 for the experimental group and 9.75 for the control group with standard deviations of 4.06 and 3.98. After adjusting scores to account for

differences in academic ability and preinstructional knowledge, the adjusted means were 10.43 for the experimental group and 9.36 for the control group.

The mean scores for the chapter six delayed test were 10.76 for the experimental group and 9.90 for the control group with standard deviations of 3.82 and 3.21 respectively. After adjusting scores to account for differences in academic ability and preinstructional knowledge, the adjusted means were 11.12 and 9.65 for the experimental and control group respectively.

The science preference score was measured by the Subject Preference Inventory prior to beginning chapter five and shortly after completing chapter six. Kendall's coefficient of consistence was used to estimate the reliability of this measure and yielded a value of .94 on both occasions. Prior to beginning chapter five, the mean science preference scores were 2.49 for the experimental groups and 2.19 for the control group with standard deviations of 1.35 and 1.63. After completing chapter six, the mean science preference scores were 2.42 for the experimental group and 1.83 for the control group with standard deviations of 1.46 and 1.62.

Means and standard deviations for both groups on all measures collected are summarized in Table 3.

TABLE 3

Means and Standard Deviations for Achievement Scores and Subject Preference Inventory (SPI)

		Experimental group	Control group
Chapter five pretest	N	42	61
	M	5.80	6.79
	SD	2.13	2.17
Chapter five posttest	N	42	61
	M	13.88	14.70
	Adjusted M	14.35	14.38
	SD	3.68	3.50
Chapter five delayed test	N	42	61
	M	9.86	9.75
	Adjusted M	10.43	9.36
	SD	4.06	3.98
Chapter six pretest	N	42	61
	M	7.86	8.07
	SD	3.00	2.41
Chapter six posttest	N	42	61
	M	11.98	11.05
	Adjusted M	12.34	10.80
	SD	3.32	2.95
Chapter six delayed test	N	42	61
	M	10.76	9.90
	Adjusted M	11.12	9.65
	SD	3.82	3.21
PRE SPI	N	37	74
	M	2.49	2.19
	SD	1.35	1.63
POST SPI	N	48	78
	M	2.42	1.83
	SD	1.46	1.62

ANALYSIS OF DATA

In this section, the data described earlier are analyzed to determine the acceptability of the null hypotheses.

Comparing Immediate Achievement

Multivariate analysis of covariance was employed to determine if differences in immediate posttest scores were statistically significant. The covariates used were academic ability as measured by the Otis-Lennon School Ability Test and preinstructional knowledge as measured by the pretest. The multivariate test of significance indicated a significant difference between the two groups and provided the justification for examining each unit test. The univariate analysis of covariance for each unit using the same covariates described above revealed a significant difference between the two groups on chapter six favoring the group experiencing laboratory activities prior to other teacher-directed instruction. The difference in the immediate achievement of the two groups on chapter five was not statistically significant. The first null hypothesis was rejected. The data are shown in Table 4.

TABLE 4

Multivariate and Univariate Analysis of Covariance Comparing Immediate Achievement Scores for the Experimental and Control Groups

	Wilks Lambda	DF	F	Level of Sig
Multivariate analysis of Immediate Tests	.910	2,97	4.81	.010

	Group SS	Error SS	DF	F	Level of Sig
Chapter five Immediate Posttest	.01876	755.96	1,98	.00	.961
Chapter Six Immediate Posttest	56.17	610.21	1,98	9.02	.003

Comparing Delayed Achievement

Multivariate analysis of covariance was also employed to determine if delayed posttest scores differed significantly. Again, the covariates used were academic ability as measured by the Otis-Lennon School Ability Test and preinstructional knowledge as measured by the pretest. As with the immediate achievement measures, the multivariate test of significance indicated a significant difference between the two groups and provided the justification for examining each chapter test. The univariate analysis of covariance for each chapter, using the same covariates, again revealed a significant difference

between the two groups on chapter six favoring the experimental group. As with the measures of immediate achievement, differences in the delayed achievement of the two groups on chapter five were not statistically significant.

The second null hypothesis was rejected. The data are shown in Table 5.

TABLE 5

Multivariate and Univariate Analysis of Covariance Comparing Delayed Achievement Scores for the Experimental and Control Groups

	Wilks Lambda	DF	F	Level of Sig
Univariate Analysis of Delayed Tests	.931	2,97	3.66	.029

	Group SS	Error SS	DF	F	Level of Sig
Chapter Five Delayed Posttest	26.63	890.04	1,98	2.93	.090
Chapter Six Delayed Posttest	50.74	749.73	1,98	6.6	.012

Graphs of the comparison of the achievement scores for each chapter are shown in Figures 3 and 4.

Comparing Science Preference

The differences between the two groups in preference for science after the second unit was analyzed using analysis of covariance. Science preference prior to the first unit was the covariate. As indicated in Table 6, the difference between the two

FIGURE 3
COMPARISON OF ALL ACHIEVEMENT
SCORES FOR CHAPTER FIVE

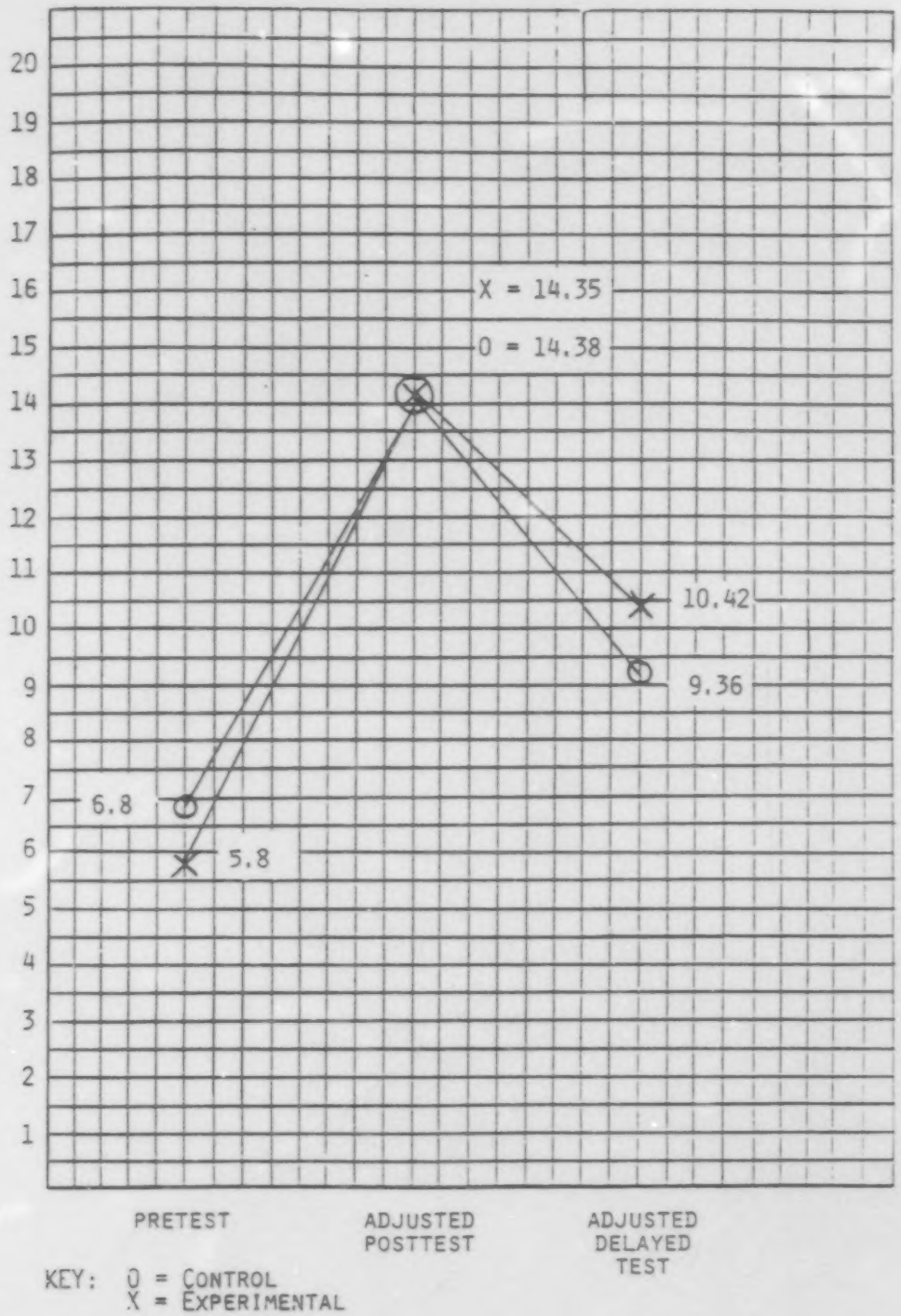
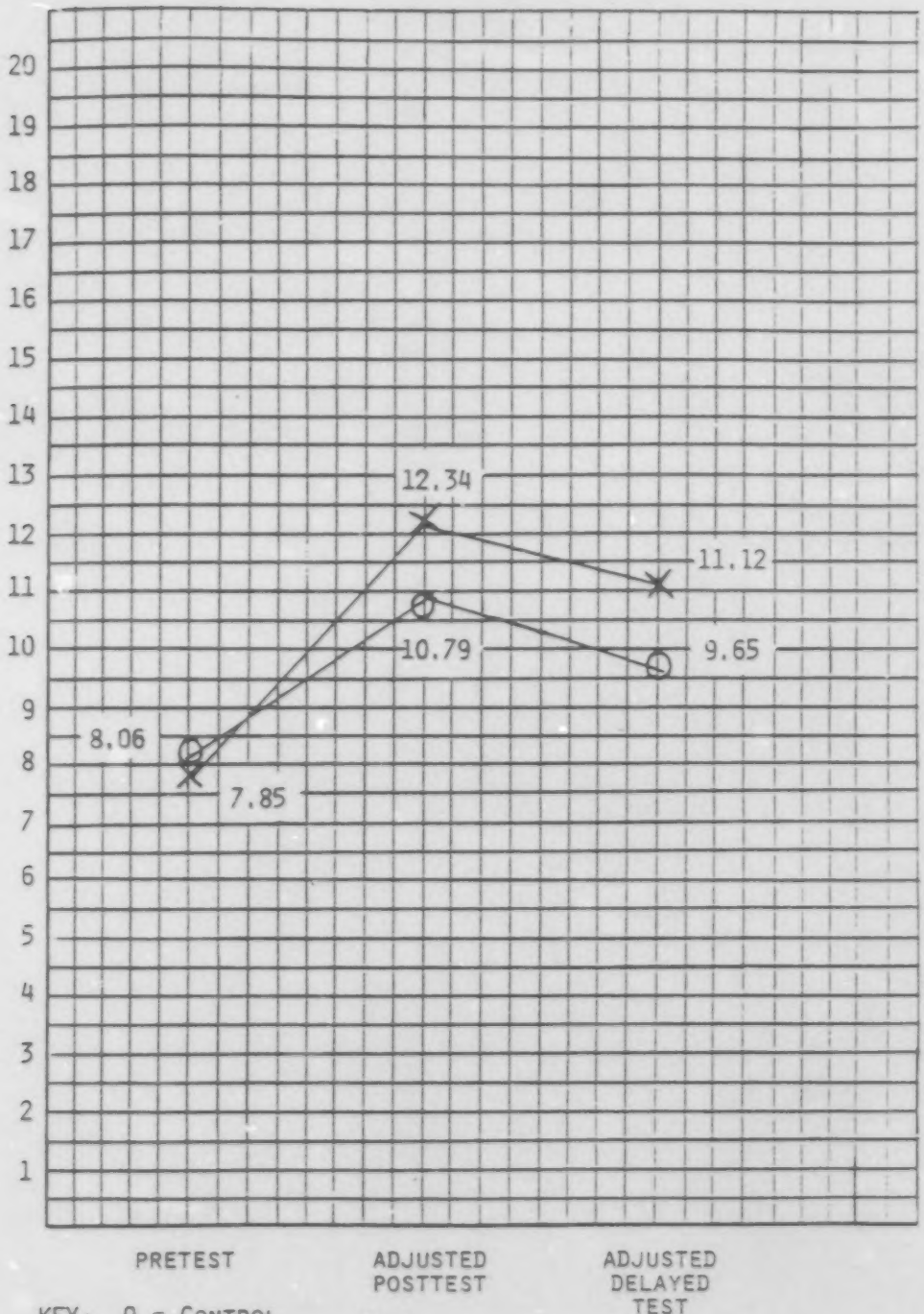


FIGURE 4
COMPARISON OF ALL ACHIEVEMENT
SCORES FOR CHAPTER SIX



groups was not statistically significant and the third null hypothesis was not rejected.

TABLE 6

Analysis of Covariance Comparing Science Preference Scores for the Experimental and Control Groups

	Group SS	Error SS	DF	F	Level of Sig
Science Preference	1.39	212.93	1,106	0.69	.41

SUMMARY

Data analysis resulted in rejecting the hypothesis of no difference between the two groups in immediate and in delayed achievement. In both cases, group achievement favored those experiencing laboratory activities prior to other teacher-directed activities for chapter six only. The differences in achievement for chapter five were not statistically significant for either the immediate posttest or the delayed posttest.

The hypothesis of no significant difference between the two groups in science preference after completing chapter six was not rejected.

A summary of the study with further conclusions and recommendations for future investigations follows.

CHAPTER V

SUMMARY

The purpose of this study was to determine if the sequencing of laboratory activities affected student achievement and preference for science. More specifically, the study was designed to answer the following questions:

1. Do students introduced to science concepts through the use of directed discovery learning laboratory activities learn those concepts better than students introduced to concepts through textbook readings or teacher lectures followed by verification labs?

2. Do students introduced to science concepts through directed discovery learning laboratory exercises demonstrate better retention of those concepts than students introduced to the concepts through textbook readings or teacher lectures followed by verification labs?

3. Do students introduced to science concepts through directed discovery learning laboratory exercises develop a greater preference for science than students who experience verification labs?

Subjects for the study consisted of students enrolled in the seventh grade earth science class at a suburban junior high school in Cincinnati, Ohio during the Fall Quarter, 1984. The students were homogenously grouped according to their academic abilities and recommendations of the sixth grade teachers. The study used two instructors each of whom taught one "advanced" and two "general" classes. The instructional units covered chapters five and six in FOCUS ON EARTH SCIENCE published by Charles E. Merrell Publishing Co. (Bishop et. al. 1981). Students were administered a pretest consisting of forty items covering concepts from both chapters, an immediate posttest after each chapter consisting of twenty items each and a delayed posttest of forty items four weeks after the conclusion of the study.

All students were administered a pre and post Subject Preference Inventory (SPI) by their English teachers to determine if the treatment affected student preference for science. The English class was used so science scores would not be biased.

Multivariate analysis of covariance was used to compare groups. Intellectual ability, measured by the Scholastic Ability Index (SAI), and pretest achievement scores were used as covariates. The results indicated that students in the directed discovery laboratory

group did not score significantly higher on the chapter five posttest but did score significantly higher on the chapter six posttest (alpha .05). The delayed posttest scores revealed no significant difference between the two groups for chapter five but did indicate a significant difference between the group scores for chapter six (alpha .05) favoring the directed discovery laboratory group.

Group differences in preference for science at the end of the study were analyzed using analysis of covariance with pre-study preference as the covariate. The difference between the directed discovery and verification lab groups was not statistically significant.

CONCLUSIONS

The conclusions are divided into two sections. The first reports conclusions related to cognitive achievement differences between the groups and the second addresses preferences for science.

Achievement

Multivariate analysis of covariance, with intellectual ability (SAI) and student pretest achievement scores used as covariates, indicated a significant difference between the two groups favoring those who had experienced directed discovery learning

laboratory activities. The improvement was present on both the immediate and delayed tests. Follow-up analysis revealed that students in the treatment group did not score significantly higher on the chapter five posttest and delayed posttest but did score significantly higher on the chapter six posttest and delayed posttest.

One possible explanation for the difference in the scores between the two chapters used in this study is that chapter five included only two laboratory activities while chapter six included four. The chapter five activities may have provided the practice with the process skills necessary to perform the DDLLs in chapter six since the students had had virtually no similar laboratory experience. The laboratory activities in chapter six may have also provided students more opportunity to modify cognitive structure than the laboratory exercises in chapter five. Support for this notion can be found in work done by Welch et al. who found that students were better able to generate their own explanations for a phenomenon when the the phenomenon was familiar to them as in verification labs (Welch et al., 1981). Students, therefore, may initially find it easier to work through a verification laboratory exercise where the results are already known because of the readings and

discussions than to perform an exercise that is discovery in nature.

A second possible explanation for the difference in the scores between the two chapters used in the study is that teachers may not have been adequately prepared to implement the directed discovery laboratory approach. Research indicates that teacher participation in designing lessons is important in the development of process teaching skills since teachers have historically not been adequately trained to guide students in labs that are exploratory in nature (Welch et.al., 1981). Therefore, the lack of teacher involvement in planning the directed discovery learning labs (DDLL) may have contributed to the difference in achievement between the two chapters.

Without training or participation in developing the DDLLs, instructors may have needed time to become accustomed to teaching the DDLLs, even though students in both groups used the same direction sheet for the laboratory activities. When teaching the control or verification lab group, for example, the instructor was free to answer student questions without regard to the development of process skills such as classifying and organizing since the students were not involved in discovery activities and already knew what results to

lab, could look in the book for the characteristics of the rocks that were to be included in the data table. The DDLL approach, on the other hand, encouraged the teacher to lead or direct the students as they worked through the lab exercises. The teachers, therefore, may have needed to learn how to help students without giving them answers to problems they might have encountered.

Another possible reason for the difference in achievement between the two chapters is that students may need an adjustment period for learning how to take a test written by someone other than their own teacher. The instructors involved in this study, for instance, reported that most of the questions on tests administered to the students prior to this study were knowledge questions while the questions associated with this study included comprehension and application questions as well as knowledge questions.

Science Preference

Analysis of covariance used to statistically analyze the difference between the subject preference inventory (SPI) pretest and posttest science scores indicated no difference in student preference for science as a result of the treatment.

The failure of the treatment to develop a greater preference for science may have been due to the short

time period of the study. A change in science preference would probably reflect an attitude change. Attitudes are changed as a result of positive reinforcement, classical conditioning, social pressures, or cognitive dissonance (Zimbardo, 1977). Students in this study did not systematically experience any of these attitude-changing events, at least not until after the post SPI had already been administered. The failure to find a significant difference probably reflects the lack of an attitude-change treatment. However, if students become aware of improved science learning, they may associate science with success and subsequently develop more positive attitudes toward science and an improved preference for science as a subject of study.

THE SUCCESS OF THE DDLL

Support for employing laboratory activities before textbook readings or classroom discussions can be found in the work on the learning cycle done by Renner et. al. who determined that students experiencing laboratory activities as an introduction to science concepts not only prefer that sequence of instruction over the verification lab sequence but demonstrate greater achievement (Renner et. al., 1985). Schneider and Renner reported an effect of .7 to 1.5 standard deviations in favor of students using the learning

cycle (Schneider and Renner, 1980). In the present study, the "effect size" of the treatment adjusted for scholastic ability and pretest scores was .47 standard deviaions on the posttest and .42 standard deviations on the delayed test, both favoring the students in the DDLL goup

Using the learning cycle, however, requires a complete revision of the curriculum in order to accomplish the results. Most science teachers do not have the time or expertise to completely revise a curriculum and are more likely to use available textbooks, equipment and instructional aids when planning and implementing lessons. The results of this study suggest that teachers interested in helping students increase achievement and retention of science concepts could do so by using existing laboratory activities to introduce concepts rather than verify them.

The DDLL applies the information processing theory which suggests that learning can be improved by using three approaches to develop sound cognitive structure. They are:

1) providing concrete experiences that allow students to establish cognitive categories;

2) providing distinctive features of the concepts to be learned from the exercise; and

3) providing students opportunities to learn the relationships among the cognitive categories (Smith, F., 1975).

The process of modifying cognitive structure requires general information and specific information. General information contains a problem and the possibility of hypothesizing a solution to the problem. To learn the difference between two minerals, for example, the learner must be in a situation in which distinctions between can be made.

Specific information is information directly related to the problem and is needed by the individual to attain a solution. The three ways an individual can collect specific information for learning are direct experience, demonstrations, and expository learning.

Expository learning is the most difficult and misleading method of acquiring information. Facts are hardest to learn, and more likely to be forgotten, when they are not relevant to the learner.

Effective demonstrations must be accompanied with verbal instruction or students may focus on unimportant or irrelevant aspects of the demonstration. The instruction may overload the student's capacity to memorize what is going on and interfere with learning.

A laboratory experience, on the other hand, provides the direct experience needed to facilitate the learning process by building a cognitive structure necessary to learn specific information.

Sometimes the interrelationships of knowledge in memory creates confusion since certain words can take on double meanings. Furthermore, verbal explanations of concepts may not be entirely clear to students. The DDLL may help to alleviate confusion by establishing mental images for students that provide a route to long-term memory. When the instructor introduces new terms, students will have a previously established anchor for the new ideas and concepts. Students, therefore, are processing information by classifying and organizing ideas rather than memorizing facts.

A second explanation for the improved achievement and retention with directed discovery learning laboratory exercises is that DDLL activities arouse student interest. According to Smith, a prerequiste for learning is that an individual must be in a new or novel situation which can be related to something already known (Smith, F., 1975). The DDLL may provide a richer background of concrete experiences to which subsequent reading and classroom discussions can be related.

REFLECTIONS

In addition to the conclusions formed after testing the hypotheses of this study, several relevant reflections are now reported. This section is devoted to those reflections.

While statistical treatment of the data generated by this study indicated improved achievement and retention for the DDLL group, the overall test scores were low. The low scores are not suprising for two reasons. First, students are not accustomed to answering questions that test for comprehension or application. On several occasions, students involved in the study informed their teachers that they knew the answer to questions they had missed but just didn't think when they marked their answer sheet. Secondly, students tend to study for tests according to the kinds of questions their instructor would ask. Since the instructors did not write the tests, the students needed time to "learn" how to prepare.

The attitudes of the students in the DDLL group did not change as a result of the treatment. It is possible that the attitudes toward science would have improved if the study had been extended for a longer period of time to allow students to perceive an improvement in their test scores. This hypothesis is supported by Mager (1968).

IMPLICATIONS AND RECOMMENDATIONS

For many years science educators have attempted to define the role of laboratory activities in the curriculum. Because no common set of objectives exists to outline the role of lab exercises, research has not been able to establish that labs are a necessary part of the science curriculum. This study, however, indicates that student achievement and retention of science concepts can be improved if laboratory activities precede the reading and discussion of concepts to be learned. Teachers should find comfort in the finding that DDLL's can be employed without a complete revision of the curriculum.

Because chapter five had only two labs and chapter six had four, studies should be done to determine how many DDLLs need to performed by students before they become accustomed to and benefit from the strategy.

An analysis of laboratory activities should be planned to determine the characteristics of lab exercises that effect modification of cognitive structure if such characteristics exist.

Further testing of the DDLL should be planned to compare directed discovery learning labs and verification labs with a no lab situation.

Additionally, future studies of the DDLL should be planned as a longitudinal study to determine the long term effects of the DDLL. The instruments used to test student achievement should be developed for greater reliability

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Appendix A

PRE AND POST SUBJECT PREFERENCE QUESTIONNAIRE

NAME _____

DIRECTIONS: Below are listed pairs of subjects that you are studying. Circle the one from each pair which you have liked the best over the past few weeks.

English ----------Music

Music----------Mathematics

Social Studies----Mathematics

Phys. Ed.---------Social Studies

Science----------English

Mathematics-------Science

Science----------Music

Music----------Social Studies

Mathematics------English

Social Studies---English

Phys. Ed.--------Mathematics

Phys. Ed.--------English

Phys. Ed.--------Science

Music----------Phys. Ed.

Social Studies---Science

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Appendix B

NAME_____

PRE AND POSTTEST FOR CHAPTERS FIVE AND SIX

IN THE SPACE TO THE LEFT, WRITE THE LETTER OF THE TERM OR PHRASE WHICH CORRECTLY COMPLETES THE STATEMENT OR ANSWERS THE QUESTION.

____1. What do we call the parent rock from which all other rocks are formed?
A. igneous
B. quartz
C. carbonate
D. metamorphic

____2. What word do we use to describe the geometric pattern of the crystal system of a mineral?
A. shape
B. luster
C. color
D. reflection

____3. What do we call the twelve minerals most commonly found in the Earth's crust?
A. elements
B. rock-formers
C. quartz
D. soil

____4. Which of the following best defines the rock cycle?
A. changes in rocks that occur at the surface
B. changes in rocks that occur at great depth
C. changes in rocks that are due to heat and pressure at depth
D. changes in rocks that occur from depth, to surface, to burial

____5. What do we call rocks that are the result of deep burial and high pressure?
A. igneous rocks
B. lava
C. sedimentary rocks
D. metamorphic rocks

____6. What forms igneous rocks?
A. pieces of other rocks
B. great heat and pressure on rocks
C. melting of rock
D. erosion

____7. Where today can we see igneous rocks forming?
A. near earthquakes
B. near volcanoes
C. in the ocean
D. at the zone of crystalization

____8. When the volcanic mountain Mauna Loa in Hawaii erupts, what do we call the hot molten material that flows down the side of the mountain?
A. magma
B. lava
C. basalt
D. quartz

____9. What would you use to help you distinguish between quartz and calcite crystals?
A. a nail
B. HCl
C. unglazed porcelain
D. a magnifying glass

____10. When Mount Vesuvius in Italy erupts, many new rocks are formed. What kind of crystals form in those rocks when the rocks cool quickly?
A. large crystals
B. small crystals
C. no crystals
D. long crystals

____11. What word do we use to describe the way light reflects from a mineral surface?
A. shape
B. luster
C. streak
D. reflection

____12. During the volcanic eruptions of El Chichon in Mexico, melted rock will rise to the surface. What do we call the melted rock before it reaches the surface?
A. lava
B. magma
C. extrusive rock
D. intrusive rock

____13. What would you use to determine if a mineral has a hardness of more than 6?
A. talc
B. a steel file
C. fingernail
D. a nail

____14. During mountain building activities rocks may undergo a rearrangement of mineral grains, an enlargement of crystals or a change in chemistry. What are the resulting rocks called?
A. metamorphic rocks
B. igneous rocks
C. magma
D. intrusive rocks

____15. Very often you can find rocks on a soccer field or a baseball diamond. What characteristic can you use to determine if the mineral in the rock is metallic or nonmetallic?
A. by its shape
B. by its cleavage
C. by its luster
D. by its color

____16. During mountain building, molten material is forced toward the surface where it hardens into a mountain core. What would we call those rocks?
A. intrusive rocks
B. extrusive rocks
C. gneiss
D. basalt

____17. During mountain building, molten material is forced toward the surface where it hardens into a mountain core. The rocks nearest the core of molten material are recrystallized. What would the above information tell you about the changes that took place?
A. the changes were caused by volcanic activity
B. the changes were caused by contact metamorphism
C. the changes were caused by sedimentation
D. the changes were caused by foliation

____18. What is the most abundant element in the Earth?
A. oxygen
B. calcium
C. iron
D. aluminum

____19. What is the parent material of the earth's crust?
A. lava
B. magma
C. extrusive rock
D. minerals

____20. When Mount St Helen's erupts, a molten material will flow down the sides of the volcano. When that hot solution cools, what will it form?
A. intrusive rocks
B. lava
C. crystals
D. magma

____21. What kind of rock could you find in a gravel driveway that was a natural rock made of a crystalline chemical compound?
A. magma
B. a mineral
C. a proton
D. a fossil

USE THE INFORMATION FROM THE FOLLOWING TABLE TO ANSWER QUESTIONS 22-26.

TEXTURE	LIGHT-COLORED----------->DARK COLORED (much quartz---->little quartz---->olivine		
Coarse-grained	Granite	Diorite	Grabbro
Fine-grained	Rhyolite	Andesite	Basalt
Glassy	Obsidian		
Porous	Pumice	-	Scoria
	Orthoclase----------->Plagioclase		

22. Suppose you found a light-colored, igneous rock with visible crystals. You could identify both quartz and orthoclase feldspar among the mineral grains. What name would you give this rock? _____.

23. What is the difference between a diorite and an andesite?
_____

24. Why would it be easier to identify individual minerals in granite compared to the minerals in rhyolite?_____
_____

25. What mineral, other than plagioclase feldspar is very common in gabbro?_____

26. Which rock would have plagioclase feldspar rather than orthoclase feldspar: Pumice or scoria?_____

IN THE SPACE TO THE LEFT, WRITE THE LETTER OF THE TERM OR PHRASE WHICH CORRECTLY COMPLETES THE STATEMENT OR ANSWERS THE QUESTION.

____27. If you were identifying minerals and were using Mohs Scale, with which of the following would be concerned?
A. hardness
B. color
C. luster
D. cleavage

____28. If you were given a mineral to identify, one of the things you might do is rub the mineral across unglazed porcelain. What would you testing for?
A. cleavage
B. luster
C. shape
D. streak

____29. The man-made diamonds that are used to make cheap rings are not considered minerals. Why not?
A. they are not hard enough
B. they are impure
C. they are not made by nature
D. they do not have the proper shape

____30. If you broke a mineral and described how it fractured along three planes, what would you would be describing?
A. texture
B. cleavage
C. color
D. streak

____31. If you were trying to identify a mineral, you might try to identity it by scratching it with various items. Which one of the following would least likely be scratched by the unknown mineral?
A. diamond
B. calcite
C. steel file
D. talc

____32. What could you use to test for the streak of a mineral?
A. a mirror
B. the side of a car
C. the back side of a bathroom tile
D. a magnifying glass

LOOK AT THE ROCKS ON THE FRONT DESK AND ANSWER THE FOLLOWING QUESTIONS.

What is the most prominant characteristic used to identify each of these rocks?

____33. Rock number 1---A. luster
B. cleavage
C. streak
D. hardness

____34. Rock number 2---A. luster
B. color
C. streak
D. hardness

____35. Rock number 3---A. luster
B. shape
C. cleavage
D. hardness

____36. Rock number 4---A. cleavage
B. color
C. hardness
D. streak

Using the key provided, identify the four rocks as either igneous or metamorphic.

37. Rock number 5_____

38. Rock number 6_____

39. Rock number 7_____

40. Rock number 8_____

Appendix C

Chapter Five Test--Minerals

NAME_____

1. What do we call a single chemical compound or element found naturally as part of the earth?
    A. neutron
    B. mineral
    C. proton
    D. fossil

2. Another test used for identifying minerals is the Mohs scale of hardness test. Which of the following minerals would not be able to scratch a piece of copper pipe?
    A. diamond
    B. talc
    C. plate glass
    D. quartz

3. If you found a mineral that had metallic luster, how would you describe that mineral?
    A. it is transparent
    B. it has a silky sheen
    C. it reflects light like a metal
    D. it is colorless

4. What clue might you use to determine if an unknown mineral is a metal?
    A. texture
    B. color
    C. luster
    D. shape of the crystals

5. Which of the following is the largest group of minerals?
    A. halides
    B. silicates
    C. oxides
    D. carbonates

6. You are given an unknown mineral that you are expected to identify. When you scratch the mineral across a piece of unglazed porcelain it produces a colored powder. What characteristic are you testing?
    A. cleavage
    B. luster
    C. hardness
    D. streak

7. What clue might you use to determine if an unknown mineral is a metal?
    A. texture
    B. color
    C. luster
    D. shape of the crystals

8. When you are trying to identify a mineral, one of the tests you might perform is to break the rock so that you could see the fracture lines. What characteristic would you be observing?
    A. luster
    B. streak
    C. cleavage
    D. shape

9. Which of the following words describes the way light is reflected from a mineral surface?
    A. cleavage
    B. luster
    C. shape
    D. streak

10. Which of the following would you use to distinguish between quartz and salt crystals?
    A. magnifying glass
    B. HCl
    C. fingernail
    D. a nail

11. If you used the geometric pattern of an unknown mineral to identify the mineral, which one of the following characteristics would you would be using?
    A. luster
    B. shape
    C. cleavage
    D. streak

12. Which of the following words describes a mineral's resistance to being scratched?
    A. cleavage
    B. streak
    C. hardness
    D. fracture

13. When molten rocks from a volcano cool, they will form solid mineral bodies. What do we call these solid mineral bodies?
    A. atoms
    B. elements
    C. molecules
    D. crystals

14. What do we call the twelve minerals most commonly found in the earth's crust?
    A. soil
    B. quartz
    C. elements
    D. rock-formers

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15. Sometimes a solution of dissolved minerals will evaporate and form a solid substance. What do we call that solid substance?
    A. magma
    B. intrusive rock
    C. crystals
    D. diamonds

16. Diamonds are an example of a mineral that may be forming deep below the volcano Mauna Loa or in other places in the world where igneous activity is occuring. Which one of the following identifies the material that forms minerals?
    A. lava
    B. crystals
    C. silicates
    D. magma

ANSWER QUESTIONS 17-20 BY USING THE KEY TO IDENTIFY THE ROCKS LOCATED ON THE FRONT DESK

17_____

18_____

19_____

20_____

Appendix D

CHAPTER SIX-IGNEOUS AND METAMORPHIC ROCKS

NAME_____

IN THE SPACE TO THE LEFT, WRITE THE LETTER OF THE TERM OR PHRASE WHICH CORRECTLY COMPLETES THE STATEMENT OR ANSWERS THE QUESTION.

1. During volcanic activity , melted rock may rise to the surface. Before the melted rock reaches the surface, the activity may stop which will allow the rock to cool and harden. What is this hardened rock called?
   A. lava
   B. magma
   C. intrusive rock
   D. extrusive rock

2. If you were trying to identify an igneous rock, you could use the texture of the rock to help you. What will the texture of the rock tell you about the rock?
   A. what the compostion of the magma was
   B. if the rock is nonfoliated
   C. how fast the magma solidified
   D. the name of the rock

3. Silicon is one of the two most abundant elements in a silicate melt. What is the name of the other element in the melt?
   A. calcium
   B. sodium
   C. iron
   D. oxygen

4. When a person is trying to identify an igneous rock, it often helps to know the composition of the rock. What does the composition of a rock tell us about a rock?
   A. the kind of minerals in the rock
   B. the size of crystals in the rock
   C. the luster of the rock
   D. the cleavage of the rock

5. If you were given a rock to identify, how would you distinquish between intrusive and extrusive rocks?
   A. compare the shape of the crystals
   B. compare the temperature of the crystals
   C. compare the size of the crystals
   D. compare the color of the crystals

6. If you were given a rock to identify, and one of the clues you had about the rock was the texture of the rock, what would you know about the rock?
   A. how the rock feels
   B. size of the crystals in the rock
   C. the luster of the rock
   D. mineral composition of the rock

7. What might be a source of metamorphic rocks?
   A. igneous and sedimentary rocks
   B. igneous rocks only
   C. sedimentary rocks only
   D. sedimentary rocks only if the rocks had crystals

8. Deep in the earth, rocks can form that are a result of a rearrangement of mineral grains, an enlargement of crystals or a change in the chemistry of a rock. What do we call these kinds of rocks?
   A. metamorphic rocks
   B. igneous rocks
   C. sedimentary rocks
   D. magma

9. What kind of rocks are banded or foliated?
   A. igneous rocks
   B. sedimentary rocks
   C. metamorphic rocks
   D. serpentine rocks

10. Why do extrusive rocks commonly have finer textures than intrusive rocks?
   A. because they cool faster than intrusive rocks
   B. because they cool slower than intrusive rocks
   C. because they have a different composition than intrusive rocks
   D. because they are formed deep inside the earth

11. What changes are involved with the rock cycle?
   A. igneous to sedimentary to metamorphic
   B. igneous to metamorphic to sedimentary
   C. sedimentary to metamorphic to igneous
   D. all of these

USING THE KEY PROVIDED, IDENTIFY THE FOUR ROCKS AS EITHER IGNEOUS OR METAMORPHIC.

12. ROCK NUMBER 1_____

13. ROCK NUMBER 2_____

14. ROCK NUMBER 3_____

15. ROCK NUMBER 4_____

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USE THE INFORMATION FROM THE FOLLOWING TABLE TO ANSWER QUESTIONS 16-20.

TEXTURE	LIGHT-COLORED----------->DARK COLORED (much quartz---->little quartz---->olivi...		
Coarse-grained	Granite	Diorite	Grabbro
Fine-grained	Rhyolite	Andesite	Basalt
Glassy	Obsidian		
Porous	Pumice	-	Scoria
	Orthoclase----------->Plagioclase		

16. What name would you give to a very fine-grained, dark-colored ingeous rock?_____.

17. How are gabbro and granite different?_____
_____

18. Which of the following igneous rocks would have the greatest amount of quartz: rhyolite, diorite, or basalt?_____

19. Circle the rocks among the following which have a history of rapid cooling.
Basalt Diorite Andesite Rhyolite Granite

20. What two basic characteristics are used to classify igneous rocks?
_____ and _____

The following appendixes include the laboratory activities for Chapter Five:

Appendix		Page
E	Crystal Formation	117
F	Identifying Rock-Forming Minerals .	118

Appendix E

CRYSTAL FORMATION

Crystals can be formed in two different ways. Think of ways you may have seen crystals form. Make a hypothesis on how you think crystals form. Write your hypotheses on your data sheet and compare them to the results of this laboratory activity.

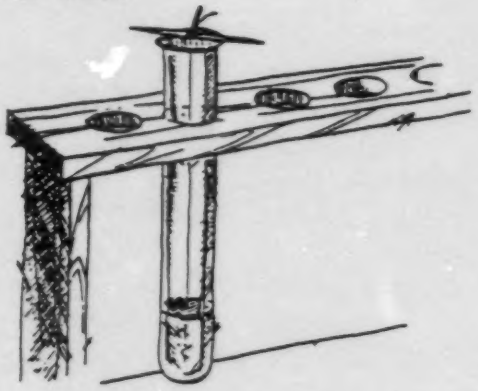
MATERIALS NEEDED:

237 ml sugar	237 ml table salt	water
shallow pan	1 large test tube	hot plate
1 tooth pick	stirring rod	thread
thermometer	1 pyrex beaker	beaker tongs
magnifying glass	test tube rack	graduated cylinder

DIRECTIONS:

1. Dissolve the sugar in 120 ml boiling water. When the sugar is dissolved, pour the solution into the test tube and place it in the test tube rack. Record the temperature of the solution.

2. Place the thread in the test tube. Be sure it does not touch the sides or bottom of the tube.



3. Cover the test tube and place it in a safe location. Leave undisturbed at least one week.

4. Dissolve the salt in 120 ml warm water in the beaker. Stir until no more salt will dissolve. Record the temperature of the solution. Pour the solution into the shallow pan and place the pan in the warmest area in the room. Leave one week.

5. After one week, examine each solution and see if crystals have formed. If they have, use the magnifying glass and carefully observe them. Draw a sketch in your table.

6. If no crystals have formed in the sugar solution, slowly add sugar to make a syrup and let stand again.

NOTE: Data can recorded on worksheet found on page 131 in the Teacher Resource Book for Focus on Earth Science (Bishop et. al., 1981)

Appendix F

NAME_____

IDENTIFYING ROCK-FORMING MINERALS

INDIVIDUALS, CALLED MINERALOGISTS, OFTEN COLLECT MINERALS AND CLASSIFY OR GROUP THEM ACCORDING TO THEIR CHARACTERISTICS MUCH THE SAME WAY WE MIGHT CLASSIFY A GROUP OF DIFFERENT KINDS OF ANIMALS OR PLANTS. LOOK AT SEVERAL MINERALS AND THINK OF WAYS YOU MIGHT CLASSIFY THEM (YOUR HYPOTHESES). WRITE YOUR IDEAS IN THE SPACE PROVIDED.

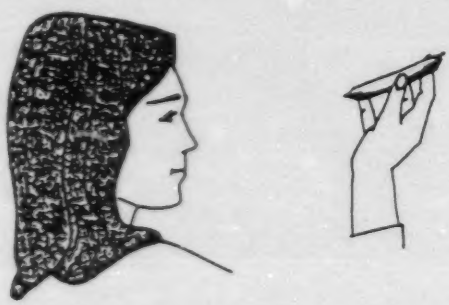
_____
_____
_____
_____
_____
_____
_____

After you have finished the lab exercise, compare what you learned in this lab with the ideas you wrote in the above spaces.

DIRECTIONS

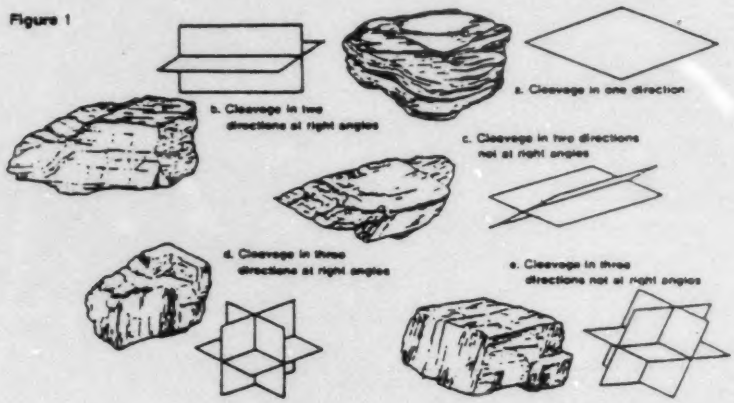
1. Pick up mineral sample #1 and carefully try to peel a layer off the top. Place a knife between the layers and lift. This peeling or separation along a smooth surface is called CLEAVAGE.

2. Hold the sample in your hand with the fresh surface up at about eye level. Now rotate the sample until you see a flash of light. Cleavage surfaces will flash in light as a mirror will if you hold it at the right angle to the sun.

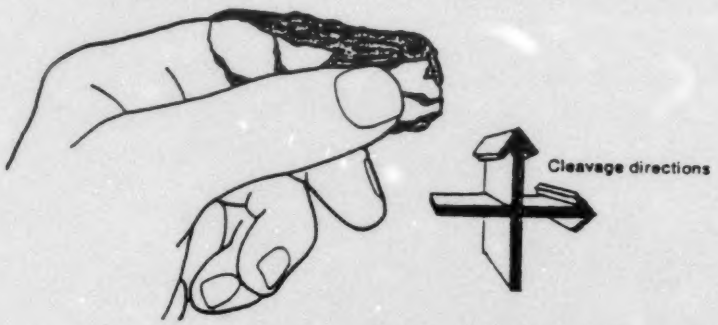


Minerals can have several cleavage surfaces. The mineral you are now holding has one cleavage surface. Examine the drawings in Figure 1. Cleavage surfaces are shown for samples having one, two, and three directions. Remember that cleavage surfaces will flash when you rotate them in good light; other surfaces will not.

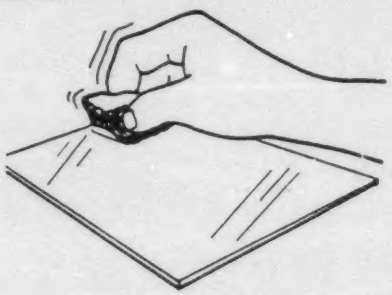
Figure 1


a. Cleavage in one direction
b. Cleavage in two directions at right angles
c. Cleavage in two directions not at right angles
d. Cleavage in three directions at right angles
e. Cleavage in three directions not at right angles

3. Pick up mineral sample #2. Hold the sample in good light and rotate, looking for flashes. You should be able to identify two cleavage directions, at about 90 degrees to each other.



4. Lay the glass plate on the table. Holding mineral sample #2 in your hand, try to scratch the glass with the sample. To determine if you have scratched the glass, rub your moistened finger across the mark. If the mark comes off, then you have not scratched the glass. If the mark remains, look closely at it with a hand lens. If you can scratch the glass with the mineral, then we conclude that the mineral is harder than glass. If you cannot scratch the glass, then the mineral is softer than glass.



You should have determined that the mineral is harder than glass. Using the same mineral, determine its luster. Luster refers to the way light is reflected from a mineral surface. There are two types of luster, metallic and nonmetallic. If a mineral looks like a metal, regardless of its color, it has a metallic luster. Non metallic luster is described as dull, pearly, silky, glassy, transparent, or brilliant.

MATERIALS NEEDED

mineral samples	copper penny	glass
streak plate	dropper bottle	graduated cylinder
5 to 7% HCl	magnifying glass	nail

PROCEDURE

Write the identifying characteristics of minerals in the empty spaces to the right of the word 'property' in the table below. Use the information just learned from the first two pages of this lab as well as information learned from observing the characteristics of minerals that have been provided by your teacher to help you fill in the blanks. Then begin the identification of the unknown minerals by recording their properties in the table below. Check for any special properties of the sample by using hyrochloric acid. CAUTION CAUTION--HYDROCHLORIC ACID CAUSES BURNS. After completion of the table, identify the minerals by using the MINERAL CLASSIFICATION CHART. Place the number of the mineral in the box marked 'sample number' next to the correct name of the mineral.

Property							
Rock #1							
Rock #2							
Rock #3							
Rock #4							
Rock #5							
Rock #6							
Rock #7							
Rock #8							
Rock #9							
Rock #10							
Rock #11							
Rock #12							
Rock #13							

FIELD SCALE OF HARDNESS

1 SOFT, GREASY, FLAKES ON FINGERS

2 SCRATCHED BY FINGERNAIL

3 CUTS EASILY WITH KNIFE OR NAIL OR SCRATCHED BY PENNY

4 SCRATCHED EASILY BY KNIFE

5 SCRATCHED BY KNIFE BUT WITH DIFFICULTY

6 SCRATCHED BY STEEL FILE OR PIECE OF GLASS

7 SCRATCHES STEEL FILE

8 SCRATCHES QUARTZ

NO APPROXIMATIONS ABOVE 8

MINERAL CLASSIFICATION CHART					
			Special Properties	Name	Sample Number
Nonmetallic luster	Harder than glass	Cleavage	2 directions of cleavage; pink, white	Microcline feldspar	
		No Cleavage	Red, brown, or yellow	Garnet	
			Olivine green; commonly in small glassy grains	Olivine	
			Transparent, milky-white	Quartz	
	Softer than glass	Cleavage	1 cleavage direction; white, greenish	Talc	
			3 cleavage directions-surfaces look like this ▢ ; colorless, white; effervesces in HCl	Calcite	
			White, colorless, gray, brown	Gypsum	
			Perfect cleavage, producing thin elastic sheets	mica	
			Dark-green to black; 2 cleavage directions	Hornblende	
Metallic luster	Harder than glass	Cleavage	Brass-yellow color; cubes	Pyrite	
		No Cleavage	Red	Hematite	
	Softer than glass	Cleavage	Heavy; silver-gray color; little cubes	Galena	

The following appendixes include the laboratory activities for Chapter Six:

Appendix		Page
G	Rock Formation	124
H	Crystal Formation	128
I	The Effect of Magna on the Surrounding Rock	130
J	Classification of Rocks	132

Appendix G

TITLE: Rock Formation

PROBLEM: Not all rocks are formed the same way. As you can imagine, there is a difference in rocks, depending on how they are formed. Some rocks are formed from the cooling of a very hot liquid that comes from deep in the earth. Do you think the rate of cooling makes a difference in rocks? Write your hypothesis and compare with your results.

PROCEDURE: Materials Needed

a. 3 small spoons or scoops
b. 1 test-tube rack
c. 3 test tubes
d. 1 alcohol burner
e. 3 small sheets of paper
f. 3 small, disposable cups
g. 1 flat metal or glass surface (aluminum foil, window glass)
h. paper toweling
i. 1 baby food jar
j. 3 beakers
k. sand
l. naphthalene flakes
m. sodium thiosulfate
n. sulfur
o. safety goggles
p. 1 test tube clamp
q. knife

CAUTION: THIS ACTIVITY SHOULD BE DONE IN A WELL-VENTILATED ROOM.

1. Cut the 3 paper cups to a shorter height and label them A, B, and C as in Figure 1.

Figure 1

2. Fill a beaker about 3/4 full of sand and scoop out a small hole in the sand. Place cup A in the hole, as shown in Figure 2. Repeat this procedure for cups B and C.

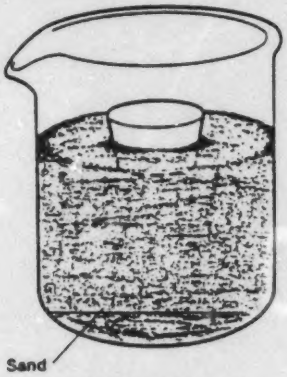


Figure 2

3. Get 3 test tubes and label them A, B, and C. Put about 5 cm of naphthalene flakes into test tube A, 5 cm of sodium thiosulfate into tube B, and 5 cm of sulfur into tube C. (The easiest way to do this is to make a crease in a piece of paper. Then spoon some naphthalene flakes, sodium thiosulfate or sulfur onto the paper. Pick up the paper and let the substances slide into the proper test tubes as in Figure 3.)

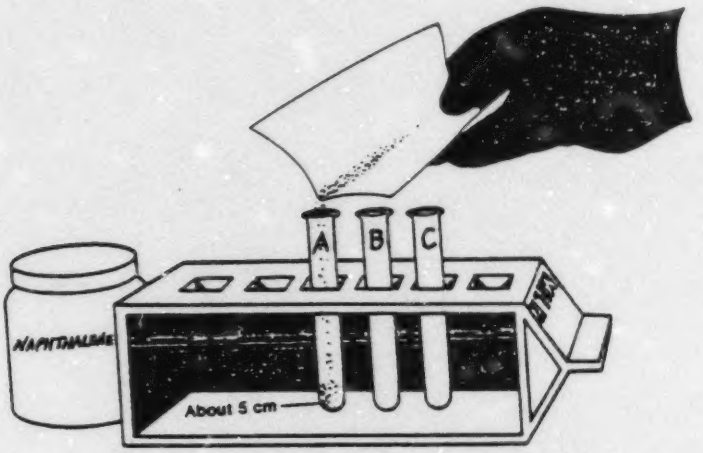


Figure 3

4. Very gently heat tube A until the naphthalene starts to melt. (Always make sure the test tube is pointed away from your classmates.) Then take the tube away from the flame and shake it gently. Heat a little more and then shake again. Continue doing this until all the naphthalene has melted. (See Figure 4.)

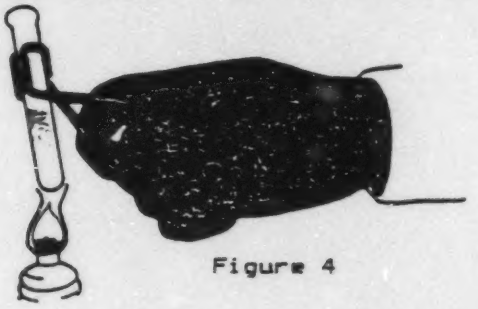


Figure 4

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5. Pour part of the melted naphthalene quickly into the cup labeled A as in Figure 5. Add just enough to fill the cup.

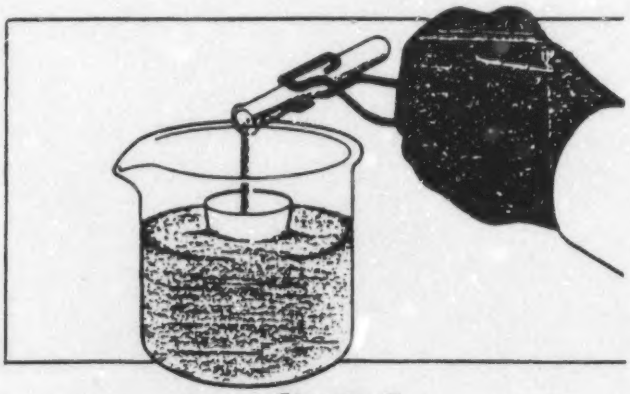

Figure 5

6. Prop the piece of glass or aluminum foil on a paper toweling and pour the rest of the naphthalene from tube A down the slope as in Figure 6.

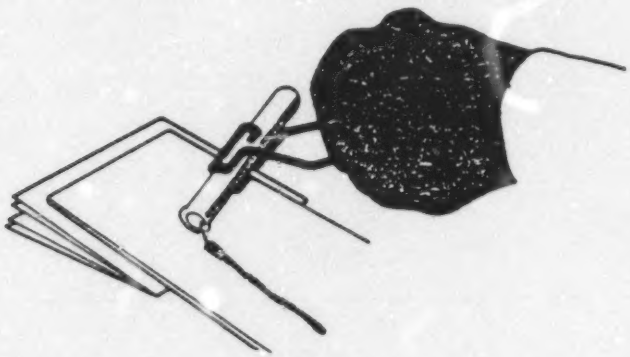

Figure 6

7. Repeat steps 4, 5, and 6 using sodium thiosulfate and sulfur. <u>However,</u> do not pour all the melted sulfur out of tube C. (Sulfur melts at a temperature of 114.5°C, forming a <u>pale-yellow,</u> free-flowing liquid. If heating continues, it becomes thicker and more viscous and, therefore, more difficult to pour from the test tube. It changes color to reddish-brown and then almost to black as temperature increases.)

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8. Make sure there is at least 1 cm of sulfur in test tube C. Heat the tube as before, to produce a pale-golden liquid. Pour the liquid into a beaker of cold water as in Figure 7.

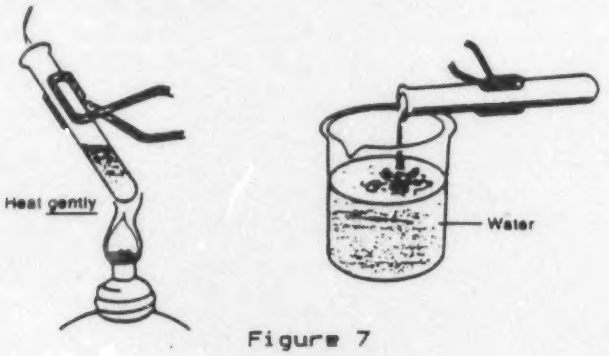


Figure 7

9. When the substance in each cup is completely solid, cut it in half with a sharp knife as shown in Figure 8.

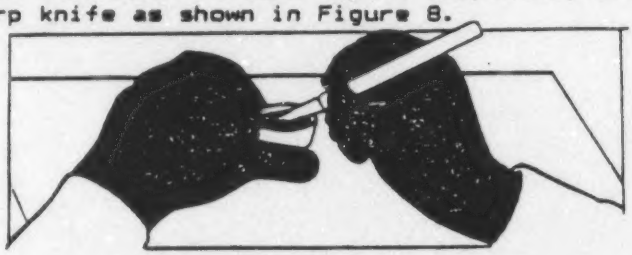


Figure 8

ANALYSIS OF DATA:

Observe the differences among the substances that were cooled by pouring down the glass or aluminum foil, cooled by pouring into a cup, or cooled by pouring into cold water. Record your observations and compare to the hypothesis you wrote at the beginning of the lab.

Appendix H

CRYSTAL FORMATION

The outer crust of the earth is composed of rocks. Rocks are composed of single minerals or mixtures of minerals. Minerals are either single elements or chemical compounds. Although 88 elements have been found in the earth's crust, eight of these make up over 98 percent of the matter of the crust. Twelve minerals, composed mainly of these eight abundant elements, are called "rock-formers" because they form the bulk of the crust.

The largest group of minerals in the crust is the silicates. Silicates contain silicon, oxygen, and some other element(s). Chemical reactions between sodium silicate and various metallic compounds form metallic silicates. These silicates precipitate as minute crystals which are held in place by the gelatinlike sodium silicate. The silicates of most metals are not soluble in water.

PROBLEM: If a silicate (a compound that contains silicon, oxygen and some other element(s)) can be chemically changed to metallic silicate crystals. Do you think there will be a difference in the size and colors of the new crystals? Write a hypothesis and compare the results with your hypothesis.

SETTING UP

- sodium silicate
- water
- 4 baby food jars
- balance
- beaker (1 L)
- magnifying glass
- metallic compounds (4 of these):
  - strontium chloride, $SrCl_2$
  - ferric ammonium sulfate, $FeNH_4(SO_4)_2$
  - copper sulfate, $CuSO_4$
  - cobalt chloride, $CoCl_4$

GETTING STARTED

1. Mix 200 g of sodium silicate in 600 mL of water. Stir until all the sodium silicate is dissolved.
2. Pour the sodium silicate solution into the baby food jars.
3. Measure 1 g of each of four of the metallic compounds. Be sure to keep the compounds separate.
4. Examine each metallic compound with the magnifying glass. Sketch the shape of the grains. Record their color, size, and any other characteristics thay you observe in Table 15-1.
5. Drop one metallic compound into each of the baby food jars. Label the jars.
6. Allow the jar to sit undisturbed for several days.
7. Use the magnifying glass to observe the crystals that form. Sketch the shape of the crystals. Record their color, size, and any other characteristics that you observe.

YOUR HYPOTHESIS

_____
_____
_____
_____

KEEPING TRACK

Metallic compound					*Metallic silicate*			
Name	*Shape of crystal*	*Size*	*Color*	*Other*	*Shape of crystal*	*Size*	*Color*	*Other*

SUMMING UP

1. List the metals that you dropped into the sodium silicate solution; for example, if you dropped ferric ammonium sulfate into the solution, the metal was iron (ferrous is Latin for iron). _____
_____
_____

2. These metals form compounds with what elements in the sodium silicate solution? _____

3. Was the reaction between the metal compounds and the sodium silicate solution a chemical or physical reaction? _____
Explain. _____
_____
_____

4. Silicates contain silicon, oxygen, and a metal. List the elements present in the silicates formed in the lab. _____
_____
_____

5. How does this laboratory activity relate to the formation of igneous rocks? _____
_____

Appendix I

THE EFFECT OF MAGMA ON THE SURROUNDING ROCK

Magma sometimes seems to rise through SOLID ROCK! How do you think this happens and what effect do you think the magma might have on the surrounding rock (called country rock). Write your hypothesis and compare it to the results of this laboratory activity.

MATERIALS NEEDED

balance
egg
meter stick
string, 30 cm
vinegar (white)
beaker (500ml)
water

PROCEDURE

1. Determine the mass and circumference of the egg. Record in the table.

2. Record characteristics such as color, hardness of shell, and smoothness of shell.

3. Place the egg in the beaker and cover with vinegar.

4. Allow the beaker to stand undistrubed overnight.

5. Pour off the vinegar and replace with water.

6. Allow the beaker to stand undisturbed for 3 days.

7. Pour off the water and examine the egg. Record its mass and circumference and any other changes.

Data Table		
Properties	Egg (before)	Egg (after)
Mass (g)		
Circumference (cm)		
Color		
Hardness		
Other		

QUESTIONS

1. Compare the egg before and after soaking it in vinegar.

2. Why dod you soak the egg in vinegar?

3. Explain, in order, the processes which caused the changes in the egg.

4. Use the process you listed above and explain how magma changes the country rock it invades.

Appendix J

CLASSIFICATION OF ROCKS

What characteristics can you use to classify igneous and metamorphic rocks? Write your ideas on the back of the data sheet and compare them to what you learn from the laboratory activity.

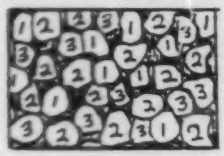
Ask yourself the following questions. As you answer each one, put a check in the appropriate box in the data table. If you reach a statement with an asterisk, then you can make a decision on the specimen at that point. You won't need to go any further in checking that specimen. When that happens, pick up another specimen and start with question 1 again.

1. Is the rock made up of visible minerals that are interlocking? If the answer is Yes, it cannot be sedimentary; go to 2 below. If the answer is No, go to item 7.

2. Do the interlocking crystals all seem to be the same mineral? If Yes, go to 3. If No, go to 4.

3. *A rock with interlocking crystals of only one mineral is usually a kind of metamorphic rock.

4. Are the different minerals evenly distributed in the rock, as shown in the following figure? (Each number in this drawing represents a different mineral.) If the answer is Yes, go to 5. If No, go to 6.



5. *A rock with different types of interlocking crystals, evenly mixed together, is an igneous rock.

6. *A rock with different types of minerals arranged in stripes or bands is a metamorphic rock.

7. Is the rock frothy (full of small holes)? If the answer is Yes, go to 8. If No, go to 9.

8. *A rock with lots of small holes, that looks as though it has been full of gas at some time, is an igneous rock formed by cooling a gassy lava.

9. Is the rock glassy like a piece of colored broken glass? If the answer is Yes, go to 10. If No, go to 11.

10. *A dark, hard rock that looks like glass is probably igneous rock formed by fast cooling of a lava flow from a volcano.

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11. Does the rock contain easily recognized particles, like fine silt, sand, or pebbles, cemented together? If the answer is Yes, go to 12. If No, go to 13.

12. *A rock made of silt, sand, or bebbles cemented together is sedimentary. It may have fossils. You can probably see the layering in good specimens.

13. Is the rock made up of strong, flat sheets that look as though they will split off into slatelike pieces? If the answer is Yes, go to 14. If No, go to 15.

14. *A nonsedimentary rock that splits easily into thin, flat sheets is probably metamorphic. The splitting has been caused by pressure. The rock was once sedimentary. If fossils are present, they are probably squashed and very distorted.

15. If you have come this far, you have a specimen that is difficult to identify. You may want to go through the questions one more time. Most likely, you will need an expert to help you sort this one out.

Check your results with the summary table which will be given to you by your teacher.

CLASSIFICATION OF ROCKS

Data Table

ROCK SAMPLE (no.)	1. Interlocking minerals?		2. Same mineral?		4. Evenly distributed?		7. Frothy (with holes)?		9. Glassy?		11. Visible particles?		13. Slatelike sheets?	
	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO

SUMMARY TABLE

TEST	SEDIMENTARY	IGNEOUS	METAMORPHIC
TEXTURE	Noninterlocking; size of minerals ranges from very large grains to invisible.	Generally interlocking; random distribution; size of minerals range from glassy to large grains.	Generally interlocking; random and oriented distribution in band or flakes; size ranges from invisible grains to very large grains
COMPOSITION	Minerals may include quartz, feldspar, calcite	Usually contains quartz, feldspar, mica; sometimes hornblend, olivine	minerals may be quartz, feldspar, mica; some contain garnet or calcite
FOSSIL	May have fossils	No fossils	If fossils are present, they are usually squashed or twisted.
CHEMICAL	May bubble with HCl	Does not react with HCl	May bubble with HCl

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